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ROBERT M. KEENEY

Does Grain Size Influence the Magnetic Properties of Iron?

T. D. YENSEN

Molding Sands

GEORGE M. ENOS

Effects of Silicon on the Properties of Brass

H. W. GOULD and K. W. RAY

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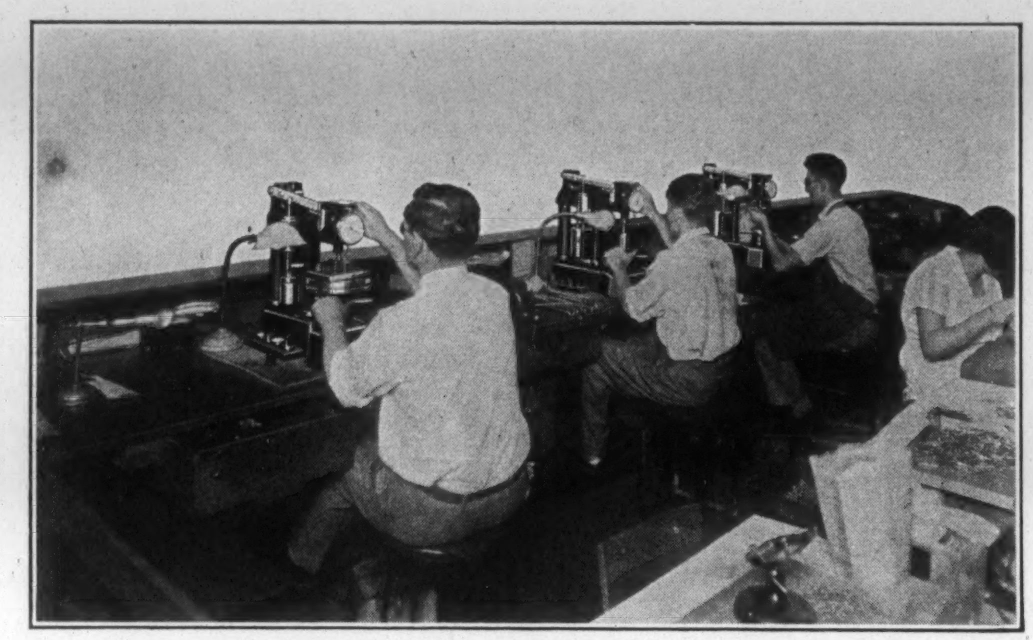

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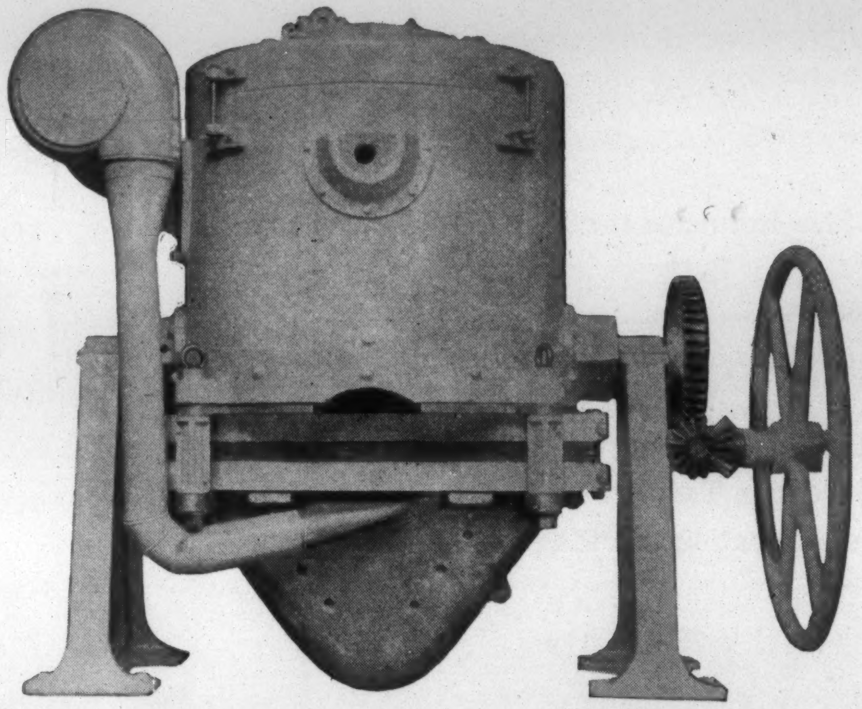

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PUBLISHER'S PAGE

Note— On this page the publishers will talk right straight to you each month. We will tell you how things are progressing with METALS & ALLOYS. *We will undoubtedly ask your advice on many points. We are publishing this paper not primarily to please ourselves but rather to serve you. And our office door is always open. You are invited to call.*

What Is a Metallurgist?

RECENTLY, in attempting to analyze the circulation of METALS & ALLOYS, we observed that 755 of our subscribers classified themselves as metallurgists; and on investigating the matter somewhat more in detail, we found that the gentlemen thus describing themselves were engaged in extremely varied lines of technical and business activities. Some of them were occupied with pure research; others with industrial research; others with sales promotion, plant management, the designing and building of equipment, or general executive activities.

It occurred to us it would be interesting to attempt to define just what a metallurgist is, or at least attempt to find out what is the most general conception of his activities. The dictionary does not afford much help. "Funk & Wagnall's" defines a metallurgist as "one versed or skilled in the theory and practice of metallurgy." Jeffries & Archer in the first paragraph of their excellent book, "The Science of Metals" say:

> "Metals have attained such an important place in engineering practice that they have been subjected to much investigation and study, resulting in a wealth of special knowledge. This knowledge is necessary for the most intelligent selection of metals for the varied uses to which they are put, for their proper processing and inspection during manufacture, and, finally, for the development of new and improved metal products."

Presumably anyone can properly be called a metallurgist who is engaged in any of the activities postulated by the above résumé of the aims and uses of metallurgical science.

One thing is certain, the typical metallurgist is not a scientific recluse absorbed in laboratory investigations. Of course, we appreciate to the full the service rendered to the advancement of science of those who are devoting their lives to such investigations. However, so quickly is every new item of knowledge about metals picked up by the industrial world and utilized, that even those whose inclination is to devote themselves to pure research often find themselves called on to guide and control industrial operations.

It would be interesting to have letters from our readers outlining their ideas of just where and how the metallurgist fits into the vast, complex organization of our modern technical and business world.

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Editorial Comment

In this department I try to comment on metallurgical and allied matters that seem to me interesting and significant. The views expressed reflect my own personal attitude. Many of our readers will have ideas of their own on these subjects and are urged to contribute them in the form of letters which will gladly be published in succeeding issues.—H. W. Gillett, *Editorial Director.*

Sentiment and Research

All research in general, and metallurgical research in particular, is done for an interesting purpose, interesting to somebody at least. There is a practical difficulty to be overcome or an economic purpose to be achieved in all industrial research. Something isn't as good or as cheap as it ought to be, and we try to make it better.

The actual work is ofttimes prosaic; it may be carried out amid the dust, heat and fumes of the foundry. Yet it is really a part of the struggle for a higher standard of living for mankind, even though this be concealed in a search for more profits for the stockholders. Research as a whole has a high moral purpose, obvious in medical research, less obvious but still real in metallurgical research.

There is often an element of drama in fundamental research oriented for a definite purpose. The need for light on some obscure relationship, or the need for more exact data, i. e., another decimal place of significant figures may require years of toilsome, painstaking work with instruments of greatest precision. Such work has a goal.

Steam tables, for example, are not dramatic. But a daily diary kept by the men who are working to extend them, and render them more accurate, recording the struggles to perfect the materials and design of the calorimeter, the set-backs due to accident, the final triumph when all the difficulties are overcome, would be a thrilling tale. Add to this a picture of the mighty engines that will result some day from the fundamentals so laboriously obtained, and a real drama could be written on the theme, though it would take a real dramatist to write it.

We can see the drama in the work of an astronomer sitting up night after night scanning the heavens, even though the work results merely in a dry set of figures in the Nautical Almanac. On the correctness of those figures may rest the safety of a great ocean liner.

There is poetry as well as drama in research work. Consider that aimed at the betterment of aviation. Who would not thrill at having a hand in making a better parachute, and in seeing the product of his toil blossom forth as the ripcord is pulled, and bear its human freight more securely to earth because of his own research effort?

Again, unoriented pure research, aimed at nothing but the extension of boundaries of human knowledge, is carried out with the spirit of the explorer, with the adventurer's zeal and joy. Its record is a book of travel.

Many a prosaic, long drawn out research struggle to corral an elusive variable achieves success only after following many false clues, abandoning them for other clues, as a result of scientific deductions and good common horse-sense, until finally the result, once the correct clue has been found, appears so absurdly simple that one is ashamed that he didn't see the only possible answer before he started. Here are the elements of a detective story. Every good research man has some of the qualities of a good detective.

Interest, drama, poetry, adventure, mystery, high moral purpose,—these are in the background in our research projects. How seldom we would guess it from the publications in which research work is recorded! When the scientist deigns to state at all the reason why he undertook the work recorded in his paper, he most often expresses it in the mildest possible terms. The initiated who themselves are working in similar lines for similar purposes, can often read the purpose between the lines. Others can only guess.

Would it detract at all from the value of the scientific results if the author so yielded to sentiment as to tell *why* he did the work, as well as what he did? It would take a little space, to be sure, but could not that extra space well be allotted if it helped make scientific papers into human documents, instead of coldly calculating, inhuman-appearing ones that might be written by a robot?

Reread Whitney's paper in our February issue on "Industrial Progress Made Through Research." Do you esteem Whitney the less because he sees and expresses the sentiment in research?

The engineer is closer to humanity than most other scientists. It is easier to read between the lines, and see the urge behind his effort, when we peruse an engineering paper, or else the engineers do not exert quite the repression that the physicist, the chemist and the metallurgist do. We recall no issue of *Mechanical Engineering* in which drama and human interest were not close to the surface in more than one paper. But how often can a metallurgical journal show an article in which it is not buried deep below the surface?

Physicists are seldom poets. The combination does exist, for there is at least one man, Paul Heyl, who is a true scientist, but nevertheless can,—and dares—express science in words of poetic beauty.

If there are metallurgists who can, and dare, put sentiment in metallurgical writings, release themselves from the inhibitions of tradition, and give the readers of their papers, a vision of the purpose behind their research, we'd like to have their papers for publication in Metals & Alloys. The editorial blue pencil will remain poised in air instead of slashing out the sentiment.

Dignity, modesty, conservatism, respect for truth, are indispensable indeed, but are they incompatible with the expression, even in terms of sentiment, of the driving force that led to the search for those new facts? Is the metallurgist really so cold-blooded a creature as one would think from the general run of metallurgical articles?

Silicon

Twenty years ago and more, there was considerable activity in the attempt to make corrosion-resistant castings of silicon or high silicon alloys. At that time, the duralumin type of heat-treatment was not understood, and it is unlikely that all the possibilities for improvement in ductility and avoidance of brittleness that would be tried out in an exhaustive investigation to-day, were exhausted in that early work.

Silica is so common that we consider it a rock, instead of an ore that contains one of our lightest and most corrosion-resistant metals. If silicon were a rare element, so that more glamour were connected with its possible development, we should probably have more of a literature of silicon than we have to-day.

Fifteen years ago, silicon was looked upon as a detrimental impurity in aluminum. To-day, the aluminum silicon alloys bid fair to be, themselves, or with other alloying elements added, the light casting alloys of the future. Metallic silicon of fair purity is an article of commerce, thanks to the demand for the aluminum silicon alloys.

Obviously, silicon, if required in large quantities, would be one of the cheapest metals.

Is it not within the bounds of reason to expect that if silicon were given anything like the research attention that has been devoted, say to tungsten, one would find ways of alloying and handling it so that its virtues of lightness, corrosion-resistance and cheapness might be utilized, and its vice, brittleness, be overcome?—H. W. G.

Readers' Views and Comments

To the Editor of Metals & Alloys:

Dear Sir: In the article on "Ocean Shipments of Ferrosilicon" in the February issue of Metals & Alloys the statement made that "Slowly cooled ferrosilicon appears to be more susceptible to crumbling than rapidly cooled material" could have been made more affirmative. Ferrosilicon—considering now only the 45 to 50% grade—is cast both in sand and in chill moulds, and manufacturers would certainly not have gone to the expense of installing pig casting machines, had they not been assured that the chill cast ferrosilicon is much more stable than the sand cast product. The only reason why chill moulds have not eliminated sand moulds is the additional cost and labor involved in casting into pigs.

The iron-silicon equilibrium diagram as constructed by Phragmen in Sweden and Murakami in Japan indicates that the "duraluminum type" of heat treatment may be applicable to alloys containing about 51 to 55% silicon, and that, therefore, depending on conditions of heating and cooling, alloys of such composition may not be stable. Disintegration may, consequently, be attributed to some internal phase change which takes place with change of volume and thus results in crumbling of the material. The greater stability of the chill cast material can naturally be explained in this way, but the explanation cannot be given for the following experiment, which the writer has described previously:[*] Take a piece of ferrosilicon which just has been tapped into a sand mould and allowed to cool down in this mould and break it in two. Soak one of the pieces in oil for a few moments and keep them both for observation. It will be found that the oil-soaked piece can be kept for weeks and months without showing a sign of crumbling while the other piece will start to disintegrate and crumble in a few days or at least within one to two weeks.

Since the cooling rate has been the same for the two pieces it goes without saying that the disintegration cannot be due to an internal phase change, since such a change can only be brought about by a difference in cooling rate. It is far more likely to assume that the disintegration is caused by the impurities—which on solidification of the ferrosilicon are rejected to the grain boundaries—being acted upon chemically by the oxygen and moisture of the atmosphere, thus forcing the grains apart. Diffusion of the atmosphere into the oil-soaked piece is, of course, considerable smaller than diffusion into the other piece and this explains the greater stability of the former. The greater stability of chill cast ferrosilicon compared with sand cast is then due to two causes: 1. The crystal structure of the chill cast product is denser and less porous, thus allowing a far smaller quantity of atmospheric air to diffuse into the product. 2. The chill cast ferrosilicon has a fine grained crystal structure while the sand cast has a coarse structure. In the former case the impurities are scattered about a much greater number of crystals. The concentration of impurities per ferrosilicon crystals is, therefore, smaller and this has the same effect as if the product were purer.

From a theoretical point of view there is nothing improbable in compounds such as carbides and phosphides of aluminum and calcium being soluble in molten ferrosilicon and on solidification rejected to the grain boundaries. From a practical point of view it is puzzling to see some ferrosilicons disintegrate within a day while others show sign of disintegration first after a week or two, despite the fact that the ferrosilicons may be consecutive casts from the same furnace where no changes whatsoever had been made as to load, temperature, raw materials, etc. It must, however, be borne in mind that it is practically impossible to keep the product at a constant silicon content. The operator naturally does all he can to keep the silicon content, say, at 47 to 48%. He can, nevertheless, not prevent that the silicon content occasionally goes up to 49 or 50% or down to 45 to 46%. The only thing which can be done practically—and which is also being done—is to store the ferrosilicon and to remelt the ferrosilicon which has crumbled within a certain time.

Very truly yours,
James Silberstein

4219 West End Ave.,
Chicago, Ill.

---

[*] *Canadian Chemistry and Metallurgy*, April 1929.

To the Editor of Metals & Alloys:

Dear Sir: The writer is a subscriber to your very excellent "Metals and Alloys" magazine and has the following request to make.

We are desirous of obtaining, if possible, a used metallurgical microscope similar to the Bausch & Lomb F S M model, which must be cheap for cash.

Anything you can do to help us locate something in this line will be appreciated.

Sincerely,
Thos. M. Gibson

Apco Mossberg Corporation,
Attleboro, Mass.

Calendar of Meetings

American Foundrymen's Association, Cleveland, Ohio, May 12–17.

American Society of Mechanical Engineers, Fourth National Aeronautic Meeting, Dayton, Ohio, May 19–22.

Canadian Chemists, 13th Annual Convention, Ottawa, Canada, May 26–28.

American Electrochemical Society, St. Louis, Mo., May 29–31.

American Institute of Chemical Engineers, Book-Cadillac Hotel, Detroit, Mich., June 4–6.

Exposition for Chemical Apparatus, Frankfort, Germany, June 10–22.

Association of Iron & Steel Electrical Engineers, Buffalo, N. Y., June 16–20.

American Railway Association Convention, Atlantic City, N. J., June 18–25.

World Power Conference, Berlin, Germany, June 16–25.

American Society for Testing Materials, Haddon Hall, Atlantic City, N. J., June 23–27.

Society for the Promotion of Engineering Education, Montreal, Canada, June 26–28.

International Exposition at Liége, Belgium, chemical and engineering sessions, Sept. 14–21.

Sociéte dé Chimie Industrielle, Liége, Belgium, Sept. 21–27.

National Metal Congress and Exposition, Hotel Stevens, Chicago, Ill., Sept. 22–27.

British Cast Iron Research Association, London, England, Oct. 29.

American Gas Association, Atlantic City, N. J., Oct. 13–17.

Association for the Advancement of Science, Cleveland, Ohio, Dec. 29–Jan. 31, 1931.

The seventeenth annual report of Director E. R. Weidlein of Mellon Institute for the fiscal year ended February 28, 1930, shows that there has been spent at Mellon Institute, during the past nineteen years, about $6,750,000. In the past year the donors, as the groups supporting the Industrial Fellowships are termed, put about $930,000 into research at Mellon Institute.

The staff for the past year included 209 full-time research men. At the beginning of the new fiscal year, 21 multiple fellowships and 40 individual fellowships were active, and 5 new ones have been accepted. Of these, 29 have been in operation for 5 years, and 15 for more than 10 years.

Many of the fellowships deal with subjects that can best be characterized as chemical engineering, especially in organic lines. The Institute's own department of pure chemical research is dealing with acidic carbohydrates and other problems in sugar chemistry. Some of the work is of metallurgical interest. Two fellowships on cast iron and one on chromium plating of aluminum have completed their work. One that became active during the past fiscal year deals with steel treatment.

Over 100 publications were made by the Institute staff during the past year.

Dr. Weidlein's report is available to all interested.

Dr. Arthur D. Little, President of Arthur D. Little, Inc., Cambridge, Mass., will address the Spring Meeting of the American Iron and Steel Institute of New York, May 9, and his subject will be "The Contribution of Science to the Iron and Steel Industry."

Does Grain Size Influence the Magnetic Properties of Iron?

By T. D. Yensen*

> *Electrical manufacturers, power plants, and all users of electricity (everybody in the country is directly or indirectly in the last category), are interested in more efficient electrical apparatus. Dr. Yensen has long been in the fore-front of research activity in the hunt for materials for better transformers, and all apparatus in which the magnetic properties of iron and steel play a part.*
>
> *It is generally recognized that the properties of silicon steel transformer sheets are related to their grain size. In this article Dr. Yensen shows that the effect of grain size appears in pure iron as well. In studying the problem, he has used iron 99.995% pure. Such refinements are characteristic of modern metallurgy.*

In order to get further data on this much debated question (see references 1–9, inc.) a number of samples of iron were prepared, taking every known precaution to get as high degree of purity as possible. Electrolytic iron made with chloride electrolyte to prevent sulphur salt inclusions was melted with small amounts of carbon (0.2–0.4%) in a high frequency vacuum furnace, as previously described by N. A. Ziegler[10] and the author.[11] The object of the carbon is to reduce the oxide that invariably accompanies electrolytic iron, the carbon combining with the oxygen to form carbon monoxide that is removed by the vacuum process. Samples with carbon and oxygen as low as 0.001% are obtainable by this means. The ingots were forged at a low temperature about 700° C. and machined into rings (2.5 cm. O. D. × 1.9 cm., I. D. × 2.5 cm. long). The rings were annealed at 950° in hydrogen for 24 hours, this treatment aiding further in eliminating carbon and sulphur. In order to obtain a variation in grain size the annealed rings were stressed by compression as described by Ziegler[12] and reannealed at 850° C. in hydrogen for 72 hours.

By this means grains varying from microscopic size (less than 0.01 mm.²) in some samples to over 200 mm.² in area in others were obtained, the latter corresponding to 3 grains in the entire ring.

The author is indebted to his associates, chiefly Messrs. N. A. Ziegler, Wilson Scott, S. L. Burgwin and H. B. Ikelman, for the preparation, analysis and testing of the samples.

Table I

Serial No.	No. Grains/mm.² Counted at 5 diam.	No. Grains/mm.² Counted at 100 diam.	Max. Permeability μ max.	Min. Reluct. ν min. × 10^5	Hyst. loss for B = 10,000 W_{10} ergs/cc./cycle	Remarks
I-22A	4.50		11650	8.60	1473	0.2 C added
B	4.43		10860	8.45	1610	
C	4.89		11230	8.92	1410	
D	6.99	109	10700	9.36	1585	
I-23A	2.64	62	16560	6.05	973	0.3 C "
B	0.004	0.46*	60600	1.65	309	
C	3.31		16560	6.05	1010	
D	0.01	0.75	48300	2.07	362	
I-24A	0.20		32900	3.04	548	0.4 "
B	0.08		36300	2.76	502	
C	0.51	9.0	31200	3.21	660	
D	0.06	3.5	37700	2.65	471	
I-25A	1.07		21825	4.58	778	0.3 "
I-26A	2.03	30.1	14170	7.08	1400	0.06 "
B	2.23		13615	7.35	1400	
C	1.99		14320	7.00	1313	
D	4.18	17.1	15000	6.67	1268	
E	2.95		14820	6.75	1282	
F	2.95		14800	6.80	1283	

* See text. Three large grains occupying over 99% of ring and 100 micro grains in 10 clusters occupying less than 1% of ring.

The results are tabulated in Table I. In Fig. 1 the hysteresis loss is plotted against number of grains /mm.² N, for the two conditions of counting grains; namely, at 5 diam. and at 100 diam. magnification. In the latter case it will be noted that the curve has not been drawn through the point representing the largest grain size. The reason for this is as follows: The sample in question is composed of 3 large grains giving a value of N = 0.004, but under a magnification of 100 diam. clusters of microscopic grains were observed here and there along the grain boundaries, the total area of these clusters being about 0.5% of the total area or 0.13% of the total volume of the ring (see Fig. 4). In other words, 3 grains occupy 99.87% of the ring volume and about 2000 grains in about 200 clusters occupy 0.13%. In such a case, it would be unreasonable to average the grain size and to say that the effective grain size is 2 mm.² (0.5 grains / mm.²). It would be better in this case to try to eliminate the effect of the clusters, and thereby to determine the hysteresis loss corresponding to a grain size of N = 0.004 grains / mm.², free from clusters. This has been done in the Appendix and the calculations show that the effect of the clusters in this case is very slight, increasing the hysteresis loss by less than 1%. We are, therefore, justified in neglecting the clusters in counting the grains and to draw the heavy curve of Fig. 1 through the point corresponding to 0.004 grains / mm.². For smaller grains the effect of the micro-grains will be proportionately greater and will assume their full effect when the flux distribution becomes uniform, which may be assumed to be the case for N = 10 or larger. The equation of the heavy curve of Fig. 1 is for W_h = hysteresis loss in ergs/cc. per cycle for B = 10,000 gausses:

$$W_h = 100\sqrt{N} + 300 \qquad (1)$$

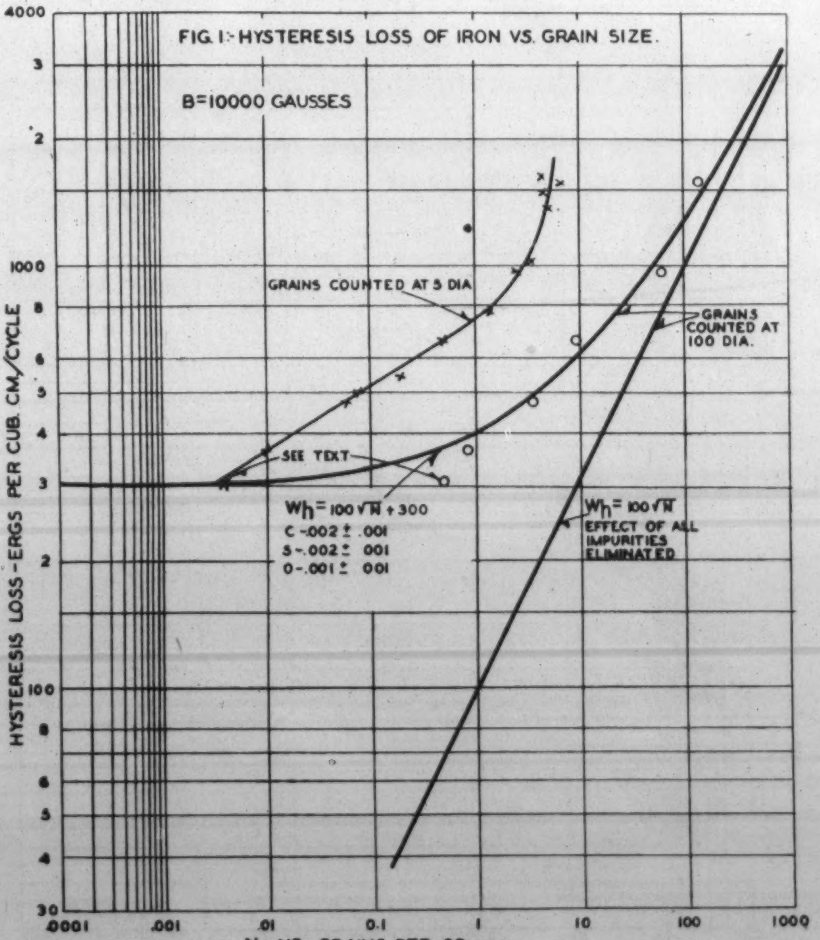


FIG. 1:- HYSTERESIS LOSS OF IRON VS. GRAIN SIZE.

---

* Research Department, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

where N = number of grains /mm.². The "300" represents the effect of the interstitial impurities in all samples alike, largely consisting of:

$$C - (0.002 \pm 0.001)\%$$
$$S - (0.002 \pm 0.001)\%$$
$$O - (0.001 \pm 0.001)\%$$

After eliminating the effect of these impurities the net effect due to the grain boundaries is:

$$W_h = 100\sqrt{N} \qquad (2)$$

as shown by the straight line of Fig. 1.

The only quantitative data previously published on this subject are those given by the author in 1924[2] and by Honda and Kaya in 1926[6] the latter using Swedish mild steel, decarbonized by means of hydrogen and subsequently stressed and annealed at 880° C. to obtain large grains. The results of these investigations, together with those of the present one, are shown in Fig. 2. In these curves, the effect of the incidental impurities have not been eliminated except of sulphur in Curve 1 on account of the relatively high sulphur content of the samples (0.02%). Curve 3 of Fig. 2 is the same as the heavy curve of Fig. 1, and represents actual hysteresis loss as measured. The similarity between this curve and Curve 1 is sufficiently good to indicate that the method of obtaining the latter in 1924 by elimination of the effect of sulphur was reasonably sound.

The large difference between the above results and those obtained by Honda and Kaya (Curve 2, Fig. 2) can largely be accounted for by the fact that the hysteresis loss in their case was measured for $B_{max} = 18{,}000$ gausses whereas Curves 1 and 3 are based on $B_{max} = 10{,}000$. Furthermore, Honda and Kaya used Swedish mild steel instead of electrolytic iron as their base, and while their samples were decarbonized, they undoubtedly retained most of the other impurities: S, P, Mn and O, both dissolved and precipitated, thus complicating the conditions.

It is, therefore, believed that Curve 3, Fig. 2 is a fairly good representation of the effect of grain size on the hysteresis loss of iron containing minute quantities of impurities, and that the effect of the grain size alone can be represented by the straight line of Fig. 1 (Equation 2).

Fig. 3 shows the results for minimum reluctivity (reciprocal of maximum permeability). The curves are similar to those for hysteresis loss and can be represented by the equation:

$$\nu_{min} = (0.6\sqrt{N} + 1.5) \times 10^{-5} \qquad (3)$$

After eliminating the effect of impurities,

$$\nu_{min} = 0.6 \times 10^{-5}\sqrt{N} \qquad (4)$$

which should then represent the minimum reluctivity due to the grain boundaries.

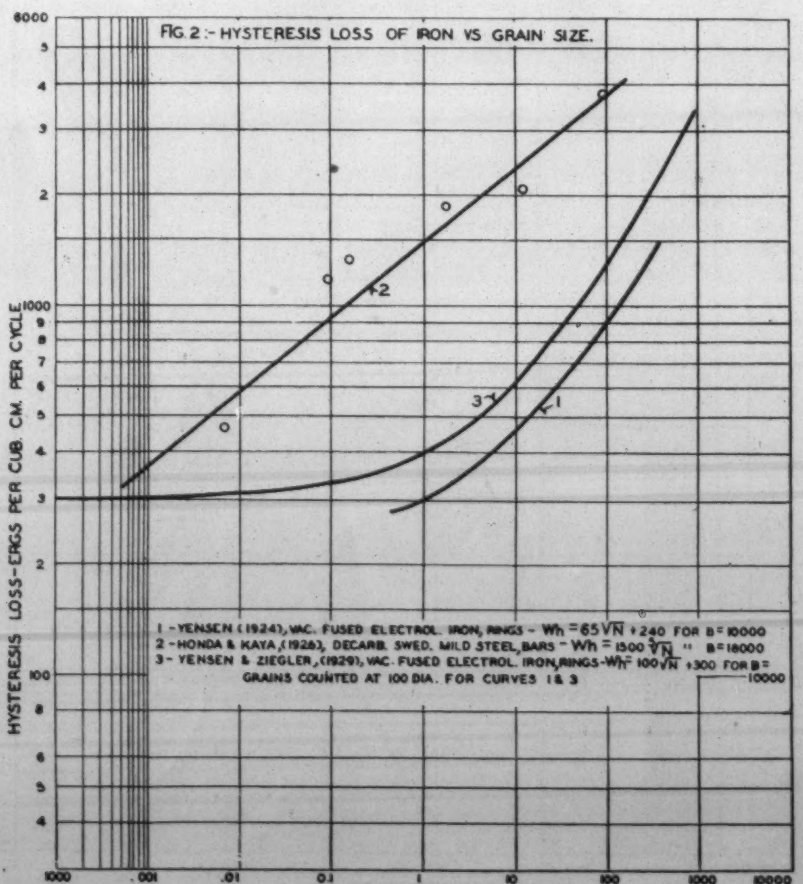


FIG. 2:- HYSTERESIS LOSS OF IRON VS GRAIN SIZE.

The above curves and equations have been determined from data obtained using unalloyed iron. As the author's previous results[2] were found to be applicable also to iron-silicon alloys, this phenomenon is probably general for all ferromagnetic materials and should be taken into account in all investigations dealing with the effect of impurities on the magnetic properties of materials.

From the results given in this paper it must be concluded that the answer to the question asked in the title of this paper is definitely in the affirmative. It remains to inquire into the cause of this relationship between the grain size and the magnetic properties.

The justification for the form of Equation 2 was pointed out by the author in 1924[2] and was based on two assumptions: (1), that there is a certain amount of material of uniform thickness along the crystal boundaries differing in crystalline structure from that of the interior of the grains and having an inherent hysteresis loss and (2), that the total hysteresis loss is proportional to the volume of this boundary material. Calculations showed that the volume of the boundary material, on the basis of Assumption 1, is proportional to $\sqrt{N}$ and consequently that the equation from the hysteresis loss should be of the form:

$$W_h = A\sqrt{N} + B \qquad (5)$$

where A is a constant, B is a parameter independent of the grain size and depending only on the impurities in the grains themselves and N = number of grains/mm.².

Honda and Kaya[6] have expressed the opinion that the increase in hysteresis loss with grain number is due to the irregular distribution of molecular magnets in the grain boundaries, and that magnetization is more difficult where the density is the greater. This opinion is in agreement with that of the author as far as assigning the increased loss to the grain boundaries is concerned.

The author's present view is that any factor that tends to distort the regular spacing of the atoms in the crystal lattice will cause a decrease in permeability and an increase in hysteresis loss. It matters not whether this factor be impurities in the form of interstitial atoms, strains due to rapid cooling or mechanical working, or interference with the progress of crystallization occurring at the grain boundaries. In most cases all these factors and perhaps others combine to give the resultant magnetic properties.

The objection to this hypothesis has been raised that ex-

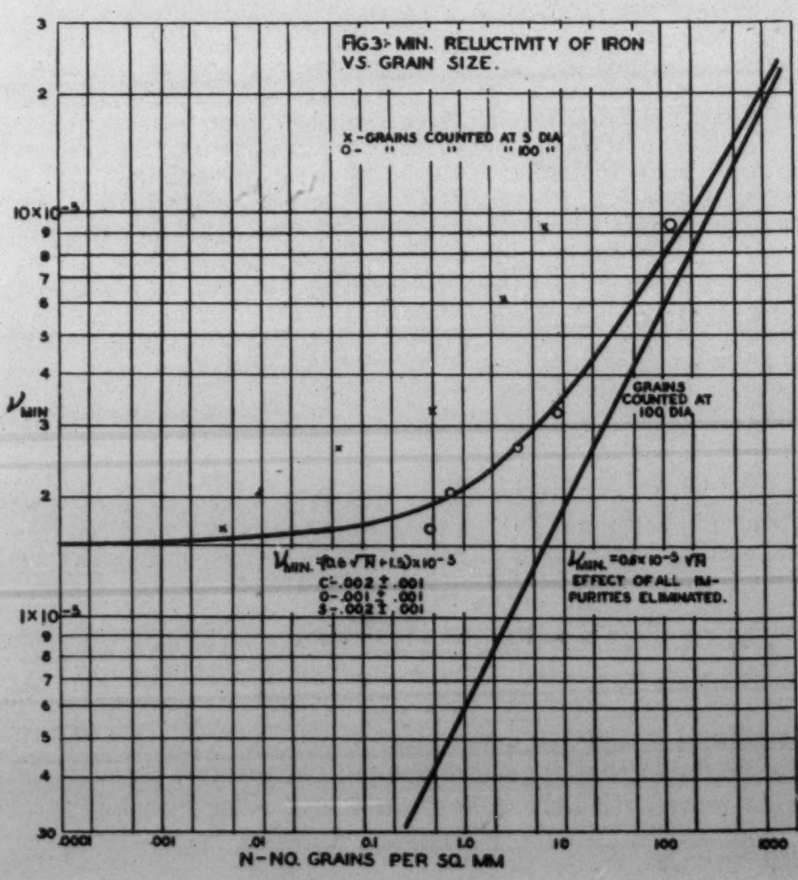


FIG. 3:- MIN. RELUCTIVITY OF IRON VS. GRAIN SIZE.

ternal tension increases the permeability of iron while compression decreases it, and as both supposedly produce distortion of the crystal lattice, the above hypothesis must be wrong. It should be noted, however, that "iron" in the latter case is not the perfect Fe crystal, but a conglomerate of crystals all containing impurities in solution and consequently already distorted before tension or compression is applied. It is conceivable that tension in such a case may decrease the amount of distortion whereas compression may increase it. It will be interesting in this connection to see if tension will increase the permeability of iron as we approach 100% Fe.

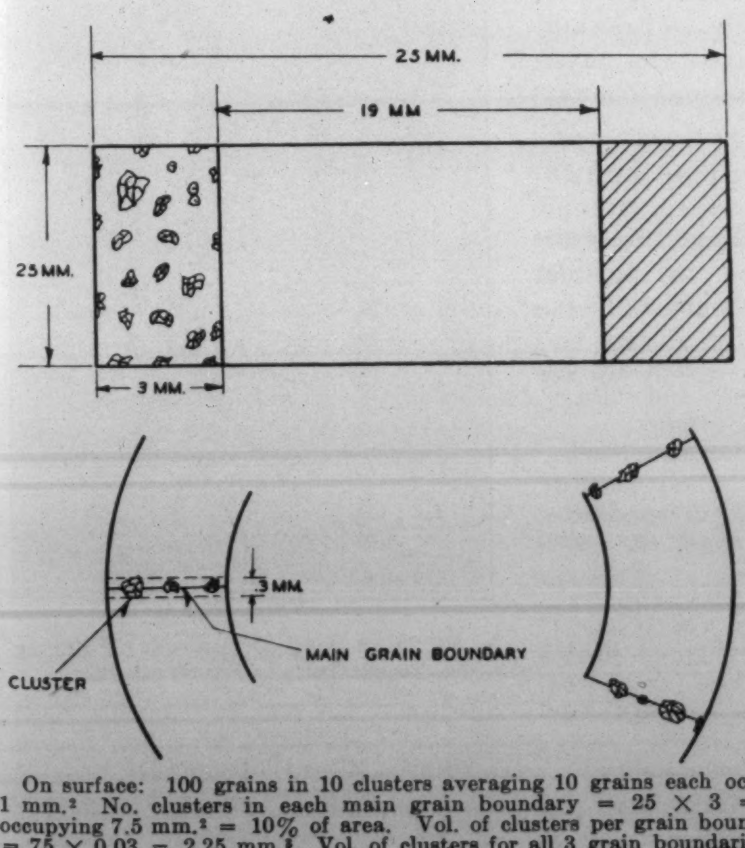
Assuming that the perfect undistorted iron crystal has infinite permeability and zero hysteresis loss and that ferromagnetism is due to the free or conduction electrons, as recent investigations indicate[13,14,15,16,17,18] why should a slight distortion—or change in distortion—of the lattice so profoundly change these properties? This is a question that will occupy the minds of investigators in this field during the coming years. It is closely connected with crystal and atomic structures. Perhaps Heisenberg's[19] recent theory of ferromagnetism coupled with Zwickey's[20,21] mosaic structure theory may help in the solution of this problem.

Appendix

Effect of Grain Clusters in Main Grain Boundaries

The magnetic "flux" (in the usual parlance of electrical engineering) takes the path of least reluctance. As there is no doubt but that the grain boundaries offer more reluctance than the grain material itself (see Fig. 3) the "flux" density in the clusters will be smaller than in the main grain boundaries. Take, for example, a zone parallel to a main boundary and 0.15 mm. wide on both sides of it (see Fig. 4). The 10 grains of the cluster, occupying 0.1 mm.^{2} area (=100 grains/ mm.^{2}), will have a minimum reluctivity of 7.5×10^{-4} (corresponding to 3.3 grains/ mm.^{2}) In other words, the "flux" density in the clusters will be about one third that in the main boundary. As the areas occupied by the clusters and the main boundary are as 1:10, the ratio of total "flux" across the two areas will be as 1:30, i. e., only 3.2% of the total flux will pass through the clusters, the flux density being 35% of the mean. The main boundary will carry 96.8% of the flux, the flux density being 106.5% of the mean. Now, let us proceed to calculate the effect of the clusters on the hysteresis loss of a sample of the same general composition as those used in this investigation.

FIG. 4:- ILLUSTRATING MAIN GRAIN BOUNDARIES WITH CLUSTERS CF SMALL GRAINS



On surface: 100 grains in 10 clusters averaging 10 grains each occupy 1 mm.^{2} No. clusters in each main grain boundary = $25 \times 3 = 75$ occupying 7.5 mm.^{2} = 10% of area. Vol. of clusters per grain boundary = $75 \times 0.03 = 2.25$ mm.^{3} Vol. of clusters for all 3 grain boundaries = $3 \times 2.25 = 6.75$ mm.^{3} Vol. of ring = $\pi \times 22 \times 3 \times 25 = 5200$ mm.^{3} Clusters occupy 0.13% of volume of ring—225 clusters—2250 grains. Clusters occupy 0.5% of surface of ring.

Let:

W_t = total hysteresis loss/cc. for B = 10,000 of the actual sample containing 3 main grains and clusters as in Fig. 4 = 309 ergs.
W_G = hysteresis loss/cc. of the grain boundary zone 0.3 mm. wide.
W_{100} = total hysteresis loss/cc. for B = 10,000 of an actual sample with 100 grains/ mm.^{2} of surface = 1300 ergs.
$W_{3\cdot3}$ = Same for an actual sample with 3.3 grains/mm.^{2} = 480 ergs.
W_o = Total hysteresis loss/cc. for B = 10,000 of a sample with no grain boundaries, i. e., of a single crystal.
V = Total vol. of ring sample = 5200 mm.^{3}.
V_G = Vol. of grain boundary zones = $0.3 \times 3 \times 25 \times 3$ = 67.5 mm.^{3}.
V_c = Vol. of clusters, containing 100 grains/ mm.^{2} = 6.75 mm.^{3}.
B_m = flux density in main boundary = 1.065 B_{av}.
B_c = flux density in cluster = 0.35 B_{av}.
B_{av} = *av* flux density.

Then,

$$W_t \times V = W_o \times (V - V_G) + W_G \times V_G \qquad (1)$$

and, assuming Steinmetz' law to hold,

$$W_G \times V_G = W_{3\cdot3}(V_G - V_c) \times \left(\frac{B_m}{B_{av}}\right)^{1\cdot6} + W_{100} \times V_c \times \left(\frac{B_c}{B_{av}}\right)^{1\cdot6} \qquad (2)$$

Substituting numerical values:

$$W_G \times 67.5 = 480 \times 60.75 \times 1.065^{1\cdot6} + 1300 \times 6.75 \times 0.35^{1\cdot6}$$

or

$$W_G = 485 + 24.2 = 509.2 \text{ ergs/cc./cycle} \qquad (3)$$

Substituting in (1), the total hysteresis loss of the actual sample is:

$$W_t = 309 = W_o\left(1 - \frac{5130}{5200}\right) + 509.2\,\frac{67}{5200} = 0.99\,W_o + 6.58$$

$$\therefore W_o = 1.01\,(309 - 6.58) = 304 \text{ ergs/cc./cycle} \qquad (4)$$

For a sample with 3 grains (0.004 grains/ mm.^{2}) without clusters.

$$W_{0\cdot004} = W_o \times \frac{V - V_G}{V} + W_{3\cdot3}\,\frac{V_G}{V} \qquad (5)$$

$$= 304 \times 0.99 + 480 \times .013$$

$$= 301 \times 6.24 = 307 \text{ ergs/cc./cycle} \qquad (6)$$

We thus find from (3) that the effect of the clusters on the grain boundary loss is to increase this by,

$$\frac{24.2}{485} \times 100 = 5\%,$$

and that the total loss of the 3 grain sample without clusters in the grain boundaries is only 2 ergs or 0.7% less than with the clusters, (307 vs. 309). The effect of these clusters can consequently be neglected and we should consider the grain size as that of the main grains only; namely, 0.004 grains/ mm.^{2} as indicated in Fig. 1.

References

[1] Ruder, *Transactions American Institute of Mining Engineers*, **47**, 569 (1913).

[2] Yensen, *Transactions American Institute of Electrical Engineers*, **43**, 145 (1924).

[3] Daeves, *Stahl und Eisen*, **44**, 1283 (1924).

[4] Von Auwers, *Zeitschrift für technische Physik*, **6**, 578 (1925).

[5] Daeves, *Zeitschrift für Elektrochemie*, **32**, 479 (1926).

[6] Honda and Kaya, *Tohoku University Science Reports*, **15**, 721 (Dec. 1926); *Research Institute for Iron Steel and Other Metals, Report* No. 138; *Nature*, **117**, 753 (May 29, 1926).

[7] Dichenberg and Oertel, *Stahl und Eisen*, **47**, 262 (1927).

[8] Oberhoffer, von Moos and Oertel, *Stahl und Eisen* **48**, 393 (1928).

[9] Von Moos, Oertel and Scherer, *Stahl und Eisen*, **48**, 477 (1928).

[10] N. A. Ziegler, *Transactions American Institute of Mining Engineers, Iron & Steel Div.*, 428 (1929).

[11] T. D. Yensen, *American Electrochemical Society*, 87, (Sept. 1929).

[12] N. A. Ziegler, *American Institute of Mining Engineers, Technical Paper* No. 273, Feb. 1930.

[13] K. T. Compton and E. A. Trousdale, *Physical Review*, **5**, 315 (1915).

[14] A. H. Compton and O. Rognley, *Physical Review*, **11**, 132 (1918); **16**, 464 (1920).

[15] J. C. Stearns, *Physical Review*, **35**, 1 (1930).

[16] T. D. Yensen, *Physical Review*, **32**, 114 (1928).

[17] J. Dorfman and R. Jaanus, *Zeitschrift für Physik*, **54**, 277 (1929).

[18] J. Dorfman and I. Kikoin, *Zeitschrift für Physik*, **54**, 289 (1929).

[19] W. Heisenberg, *Zeitschrift für Physik*, **49**, 619 (1928).

[20] F. Zwickey, *Proceedings National Academy Science*, **15**, No. 3 (March 1929).

[21] H. N. Evjen, *Physical Review*, **14**, 1385 (Nov. 15, 1929).

Molding Sands

By George M. Enos*

Introduction

In previous articles† the problems of pressure and support and the flow of metals in molds have been considered. In this article, it is intended to discuss the characteristics of molding sands and core sands and some of the tests commonly applied in determining the quality of the sand, either before it is used or while it is in process. Detailed descriptions of testing methods[1] not included, as these are readily available in compact form.

As has been pointed out, there are so many variables in the methods of producing castings that any attempt to control at least the most important ones is a step in the right direction. The literature of foundry practice in recent years gives ample evidence of the improvements made in sand control in the industry.

Chemistry and Origin of Molding Sands

Molding sand has two principal constituents, silica and clay or "bond." Usually more than 80% of the sand, as used, is silica. The actual percentages of constituents will vary, depending upon the use to be made of the sand. For use in a steel foundry, the silica content will be very high, since the silica is less likely to fuse when nearly pure than a sand containing considerable bond. The temperatures encountered in steel casting practice are higher than in a gray iron foundry.

When pure, clay would correspond to the formula $Al_2O_3.2SiO_2.2H_2O$, but the clay found in molding sands is usually impure. Clay results from the decomposition of igneous rocks, such as feldspars. Sands suitable for use in molding are found in several types of deposits, viz., in place, as decomposed from the original rocks, or in beds (1) deposited by glacial action, (2) from streams or lakes, or (3) by the wind.

In Table I, a chemical analysis of a typical molding sand is given, before and after use. It will be noted that the water content before use indicates "dry sand" practice. The significant changes on using are (1) the reduction of water content, and (2) change in the condition of the iron.

Table I—Analysis of a Typical Molding Sand

Formula	Name	Before Use %	After Use %
SiO_2	Silica	83.49	82.32
Al_2O_3	Alumina	7.25	7.80
Fe_2O_3	Ferric oxide	4.74	3.98
FeO	Ferrous oxide	...	2.38
CaO	Lime	0.36	0.54
MgO	Magnesia	0.35	0.41
K_2O	Potash	1.30	1.64
Na_2O	Soda	0.41	0.80
TiO_2	Titanium oxide	0.30	0.22
H_2O	Water	1.66	0.19

While most of the molding sand used comes from natural deposits, there is a tendency in modern practice to blend a high silica sand with a suitable "bond," clay or its equivalent and thus regulate the relative percentages of silica and bond within close limits. The nature of clay, with its water of hydration, is such that it will break down with continued use at high temperatures. Instead of adding new sand, the old sand heaps can be built up by addition of bonding material.

In making cores, suitable binders such as linseed oil are used with high silica sand in place of clay. Occasionally some non-mineral binder might also be used with a molding sand.

Tests Performed on Molding Sands

The testing of sands may be divided into two classes: (1) Tests made by the practical foundryman working without special equipment, and (2) tests made following some standard procedures and using laboratory equipment. Later, a comparison of the two methods will be made. The laboratory tests include chemical analysis and physical tests as follows:

Physical Tests

Physical tests applied to molding sands include:

1. Screen analysis on clay and silica
2. Strength
    - Green sand
    - Dry sand (baked specimens; cores on dry sand work)
3. Permeability
    - Green sand
    - Dry sand (baked specimens; cores on dry sand work)
4. Durability
5. Fusibility
6. Microscopic examination

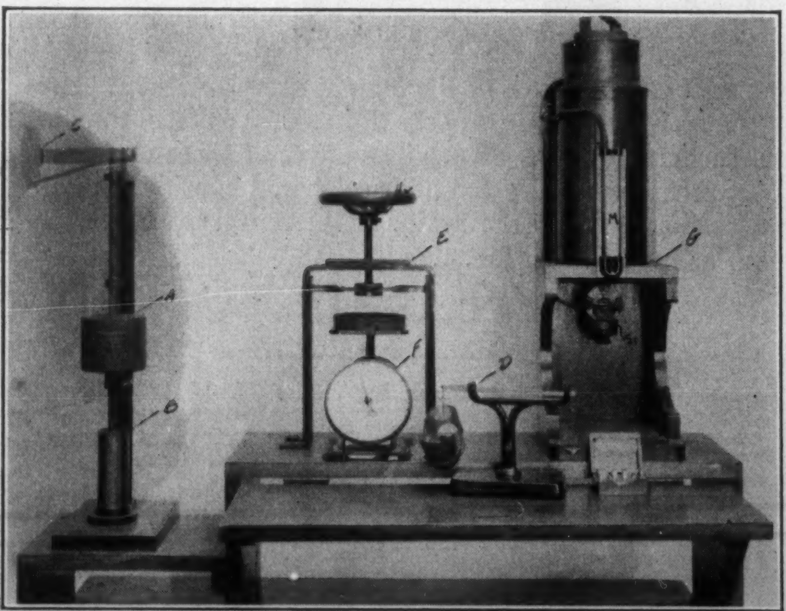


Fig. 1.—Apparatus for Testing Strength and Permeableness of Sand

The sand rammer with the specimen tube holder (B) is placed as shown at the left; the compression strength apparatus in the center, and apparatus for measuring permeability at the right. The specimen is rammed up under the rammer and is contained in tube holder (B). It is then fastened on the rubber stopper (St) of the permeability apparatus. Air is passed through the specimen under definite conditions and the permeableness is recorded on the manometer (M). The sand specimen is then removed from the tube holder and placed on the pan (Pa), under compression screw plate (Pl). The hand wheel (Hw) is revolved and the specimen broken under compression, and the resistance to compression is registered on the hand scale.

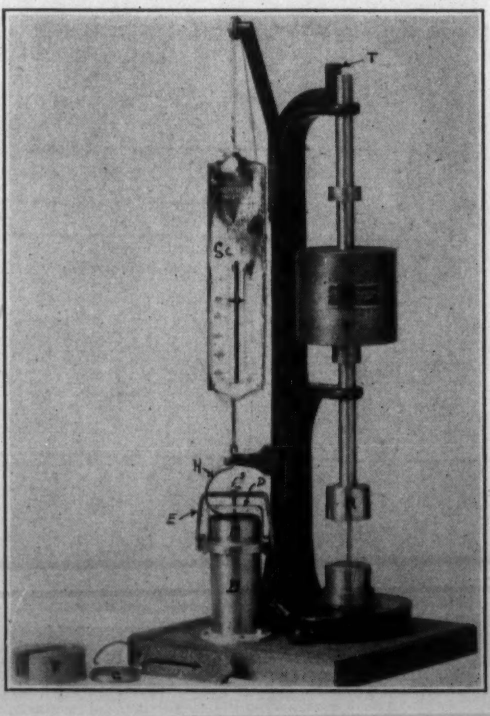


Fig. 2.—A Combination Apparatus for Making Tensile Tests on Foundry Sands

The specimen tube holder (A and B) is filled with sand and placed under the rammer-head (R). The weight (W) is then dropped three times, falling a distance of 2 inches. The specimen tube is then removed from under the rammer and the yolk (D) is put in place and the top of the specimen tube (A) is lifted from the lower section (B). The tensile strength is recorded on the scale (Sc).

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† "The Flow of Metals in Molds," METALS & ALLOYS, January 1930, Part I; February 1930, Part II.

[1] Standard and Tentatively Adopted Methods of Testing and Grading Foundry Sands, as recommended by the Committee on Molding Sand Research and approved by the American Foundrymen's Association—May, 1928.

Properties of Molding Sands

The tests applied can be taken as an indication of the properties of sand. Certain properties are fixed, others may be varied, and variations affect certain dependent properties. The *fixed properties* include the chemical composition, the ratio of the silica to the clay, the state of subdivision, i. e., the fineness, the durability and the fusibility. The moisture content and dry strength are *variables*, as their values can be changed by additions which will not seriously affect the chemical composition when the chemical analysis is figured on a dry basis. The green strength, green permeability, and dry permeability are *dependent* properties, since their values change with changes in the fixed and the variable properties. Green strength and green permeability are dependent on the moisture content and on the method of ramming. The dry permeability is dependent on the method of ramming, binders used, if any, and on the thoroughness of drying.

Definitions

It may be of interest to define certain terms used in molding sand testing.

Clay percentage is the number of parts of clay per hundred parts of sand; thus, a clay percentage of 25% would indicate that there are 25 lbs. of clay and 75 lbs. of silica (sand) in 100 lbs. of molding sand.

Screen percentage refers to the number of parts of the silica content of the sand (previously washed clean of adhering clay) remaining on given meshes of a series of screens arranged with the larger meshes at the top and gradually becoming finer to the finest at the bottom. It is understood that the grading of the sand is accomplished by a suitable shaking of the screens with subsequent weighing of the amounts remaining on each screen, and results expressed in percent.

This test indicates the fineness of subdivision of the actual sand particles. If the clay were not washed off prior to testing, the results would be misleading, as the bond, adhering to the grains of silica, would cause the retention of the silica on a screen of larger opening than would be the case if the sample were washed.

"Mesh" means the number of openings per linear inch of the screen. The exact area of the openings on any screen will depend on the diameter of the wire used. Usually this factor is not considered if the screens conform to standard specifications.

For some purposes it may be advisable to screen an unwashed sample (in case of silica core sands) so that it should always be stated whether or not the sample was washed free from clay.

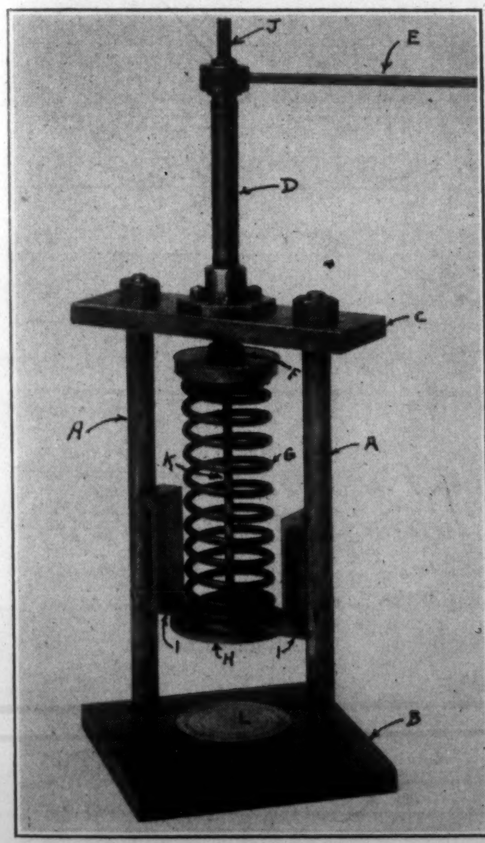

Fig. 3.—Spring Compression Apparatus

The same sand specimen used in the permeability and compression apparatus as described under Fig. 1 is used in connection with this machine. The specimen, after being rammed, is removed from the tube holder and placed on the plate L. The pressure is applied by the screw (D), revolved by the handle (E), and transmitted through the spring (G). The pressure recorded to break the specimen is read from the scale on the rod (J).

Moisture percentage is the number of parts of water per 100 parts of tempered sand.

Dry strength refers to the ability of the rammed, baked sand and binder to withstand applied stresses such as compression, tension and bending.

Green strength refers to the ability of the rammed green sand to resist compression and tension stresses.

Permeability is the venting power of the rammed sand. It may be expressed as

$$\text{Permeability} = \frac{\text{cm.}^3 \text{ of air} \times \text{cm. height of specimen}}{\text{grams of pressure} \times \text{cm.}^2 \text{area of specimen} \times \text{min.}}$$

The constants for the A. F. A. test[1] are:
2000 cc. of air to be forced through the specimen whose height is 5.08 cm. (2") and whose area is 20,268 cm.^{2} (3.1416 in.^{2}). Under these conditions the formula becomes

$$\text{Permeability} = \frac{501.2}{\text{grams of pressure} \times \text{min.}}$$

Permeability is the amount of air per minute, according to the pressure, per unit volume of the specimen, i. e., if a certain amount of air per minute for a given pressure can be passed through a specimen, then if the pressure is doubled, twice the amount of air will be passed through the same specimen in the same time, or the same amount of air in half the time.

Durability refers to the ability of the sand to stand up under service conditions. Fusion of bond and sand may change the characteristics of the molding sand. Plant tests may be carried out using continuous pouring on a given amount of the sand and the other properties of the sand tested frequently during the run. Laboratory life tests may also be run according to the method of Dietert.[2]

Fusibility. The fusion point of a molding sand will vary with the composition; that is, with the relative amounts of the various acid and basic anhydrides which are present. Finely divided sand will fuse easier than large particles. The length of time at which the sand is exposed to the high temperatures will influence the degree of fusion.

Microscopic examination. Microscopic examination of the sands yields information of value. A convenient type of instrument to use is the binocular microscope with which examinations may be made up to 30 diam. Foreign inclusions may be detected and the degree of fusion of a used sand estimated.

Methods of Making Tests and Interpretation of Results

Chemical Analysis

A proximate analysis of the sand, to determine moisture,

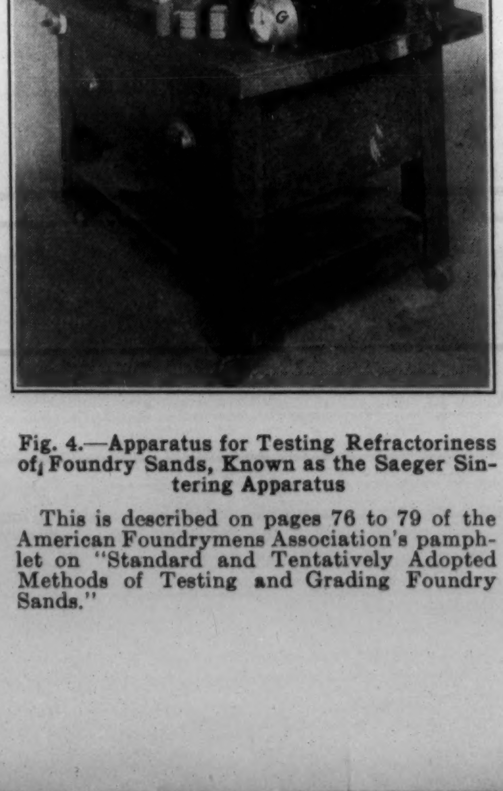

Fig. 4.—Apparatus for Testing Refractoriness of Foundry Sands, Known as the Saeger Sintering Apparatus

This is described on pages 76 to 79 of the American Foundrymens Association's pamphlet on "Standard and Tentatively Adopted Methods of Testing and Grading Foundry Sands."

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[2] "Commercial Applications of Molding Sand Testing," H. W. Dietert, *Transactions American Foundrymen's Association*, **32**, Part 2, 24 (1924).

bond and silica, will furnish results of interest and value. The determination of moisture has been standardized[1] and is considered a test of great importance in any molding sand examination. Separation of the clay from the silica grains is a definite part of the Fineness test, which has also been standardized, so that the data from the fineness test completes the items needed for the proximate analysis. Volatile organic material should be determined if it is likely to be present.

An ultimate analysis is rarely made, and interpretation of results in terms of foundry practice would be difficult, if indeed any information at all would be gained. Possibly a change in the ferric and ferrous iron percentages on a sand before and after use might yield some information regarding conditions within the mold. Of course, in detailed researches where study is made of the mineralogical nature of the bond, a complete analysis would be required.

Screen Analysis or Fineness Determination

Since the permeability of a sand is dependent upon the state of subdivision of the sand particles and ratio of clay to silica, and also because the casting finish is affected by the fineness, the Fineness test is one of great importance.

It is necessary to consider the relation of clay to silica grains, since the screen test is performed on the silica, *not* on the clay. The clay is removed by some suitable washing method, the usual method being that specified by the American Foundrymen's Association.[1] It is important to have a *standardized* set of screens, especially in the finer sizes. The sizes of screen used range from 6 to 270 mesh, by suitable intervals. The finest particles, those which will pass 270 mesh on screening the silica grains, may be comparable in size to the largest size of the clay substance, as has been shown by Crane[3] and are on the order of 15 μ diam. Since some of the clay particles are finer than this, it will be seen that with a large amount of clay present, there is every chance for the voids to be filled, and the venting power (permeability) of the sand reduced to a point where it cannot be depended upon to release gases generated or compressed in the mold.

Among other factors to be considered are the shape and surface conditions of the silica grains, the adhesiveness of the bond to the silica, and the quantity of colloidal material present.

The information gained from screen analysis may be expressed in various ways. Crane[3] used the method of Nevin[4] and typical curves are shown in Fig. 5. On one axis of a coordinate system is plotted the actual percentage of sand on each sieve, and on the other axis the logarithm of the actual sieve opening. An average size of 35 μ was assumed for the material passing No. 270 sieve. Crane suggested plotting grain size distribution curves considering only the sand grains, by recalculating the percentage left on each sieve, as percentage of screen total, on basis of washed sand grains. The variations in the curves are indicated in Fig. 5.

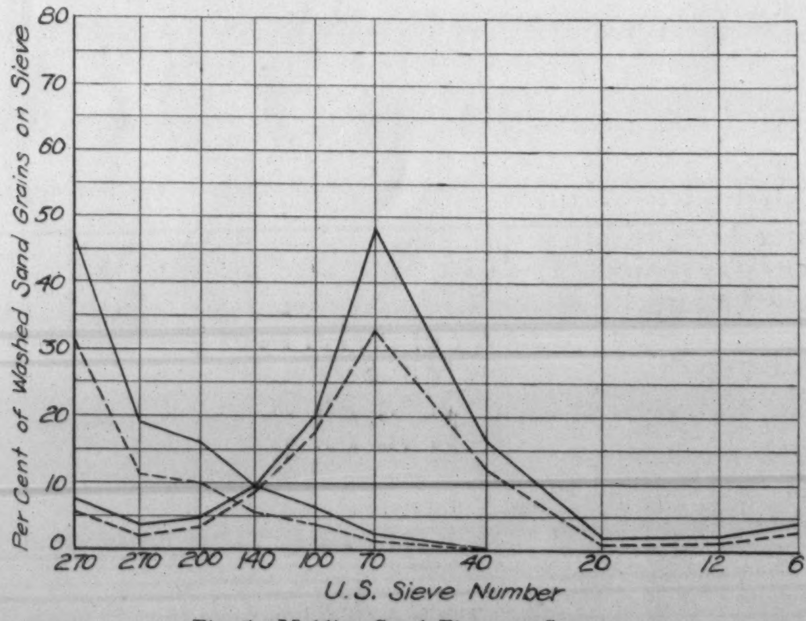

Fig. 5—Molding Sand Fineness Curves

Plotted on semi-logarithmic paper. Dotted lines plotted according to Nevin. Solid lines plotted to eliminate variation to the amount of bonding material. (From thesis of P. W. Crane.[3])

Various methods of grading have been suggested and a tentative method adopted by the American Foundrymen's Association.[1] Any method of grading sands is based first on grain size of fineness, with some reference to clay substance, refractoriness and durability.

Strength Tests

Strength, as used here, is a general term, indicating the resistance the sand offers to abrasion from flowing metal or careless manipulation of finished mold, to the force of gravity (in the cope) or to other forces. Necessarily two general strengths are indicated, "green sand" and dry sand. All sand is molded damp or "green," but larger sections, and most cores, are dried before the casting is poured.

The strength of sand depends upon the bonding power of the clay. This bonding power is explained in terms of certain colloidal phenomena. The bond contains colloidal material, inorganic gels, which, when hydrated, tend to stick the sand grains together, when the sand is rammed in place in the mold. "Green" strength, then, is *dependent* as mentioned before, on the moisture content and method and extent of ramming. "Dry" strength values are necessarily different than "green" sand values, even though original moisture content and other conditions were the same, because on drying, the gels become hard and solid, whereas in the "green" state they are plastic. So far, no general relationship between green strength and dry strength has been demonstrated.

Strength tests are made in the same general manner as strength tests for other materials; that is, tensile tests, compression tests, and transverse tests. The first one to be considered is a transverse test, measuring the "cohesiveness" of the material. One method used may be explained briefly:

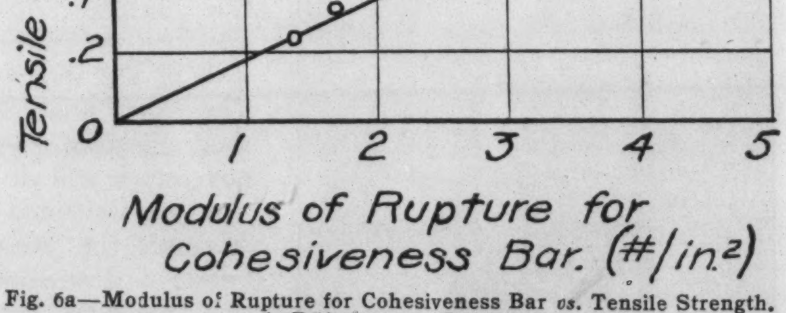

Fig. 6a—Modulus of Rupture for Cohesiveness Bar *vs.* Tensile Strength. A. F. A. tests. (Crane[3])

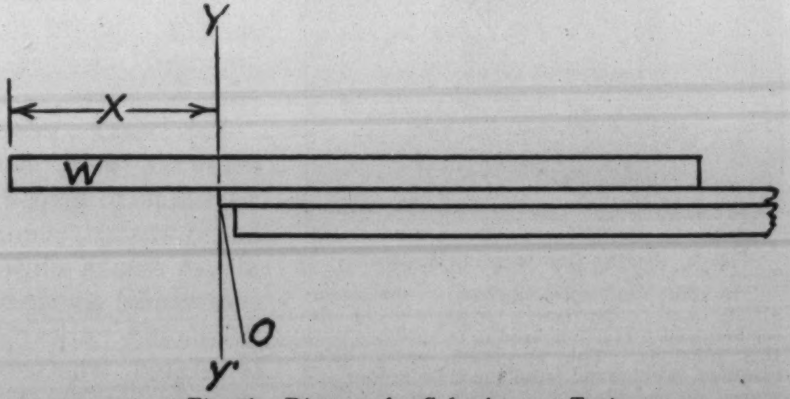

Fig. 6b—Diagram for Cohesiveness Test

The overhanging portion of sand bar, represented by distance x, with W considered as weight of cantilever beam, with a bending moment M at yy' in in.-lbs. From this data, mathematical relationships may be deduced.

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[3] "The Work of the Molding Sand Laboratory of the Commercial Club of Cincinnati," *Resource Survey*. (M. S. thesis, University of Cincinnati), P. W. Crane, 1926.

[4] "Notes on the Grading of Sands with Special Reference to Albany Sands," C. M. Nevin, *Transactions American Foundrymen's Association* **32**, Part 2, 182 (1924).

A bar of sand, uniformly rammed, 1″ high, 2″ wide and 16.25″ long is moved at a uniform speed over the edge of a table. When a portion of the bar projects a sufficient distance, it will break; thus the bar will be broken into a number of sections. The "bonding strength" may be expressed as the average weight of the broken sections. Crane[3] has studied this test from a mathematical viewpoint and concludes that the test gives only an approximate comparison between molding sands. See Figs. 6a and 6b.

A tensile strength test should measure the stress actually required to tear the grains apart. One difficulty in making the test is in securing the ends of the specimens, especially in green sand work. On dry sand work, briquettes can be molded, dried and tested in a standard cement testing machine. Methods developed by Grubb[5] and by others for green sand work involve ramming the sand specimen, (which may be of same dimensions as permeability specimen, to be described later) in a cylinder made in two parts and clamped together during the ramming. The placing of the parting line, or joint, is such that when the lower part of the cylinder is fastened to a base, the clamps may be removed and tension applied to the upper part of the cylinder. Thus pulling apart the sand. Various investigators have used different designs of cylinders and different methods of measuring applied force.

Compression tests have been studied by numerous investigators. Obviously different size samples and different methods and rates of loading have been tried.

The American Foundrymen's Association standard method[1] on green sand, after describing apparatus and technique, reads:

> "The compression test shall be made on the green sand permeability specimen after it has been removed from the permeability cylinder, by applying a load uniformly to the two plane surfaces of the specimen at the rate of 30 lbs. per min., with a leeway of 10 lbs. per min. in either direction, the load to be applied along the axis of the cylindrical specimen."
>
> Additional information regarding averages, etc., is also given.

A diagram of a suitable compression machine is given in Fig. 7. Crane has pointed out that with sands containing ordinary bond content, the failure in compression is usually along conical surfaces and is thus an indication of failure by shear. "The angles which the sides of the cones made with the line of action of the compressive force were found to be very nearly 35°, for a large variety of sands." See Fig. 8. The mathematics of shear in brittle materials can be found in standard references on strength of materials. Crane also plotted tensile test values against compressive strength values (remembering that the compressive strength values are also indicative of shearing stress) on a number of sands, and his results are indicated in Fig. 9.

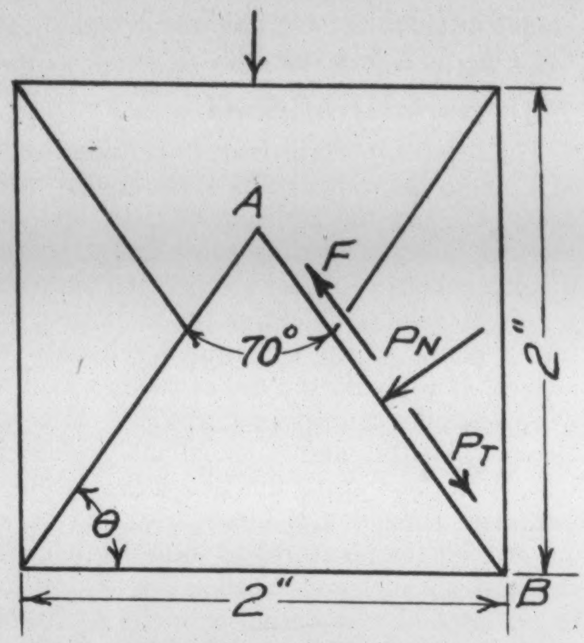

Fig. 8—Diagram Showing Failure by Shear in Compression Testing of Molding Sand

Permeability

As in the case of strength values, there are two types of permeability, green sand and dry sand. If the clay bond is washed out, the permeability can be measured on the sand grains and is known as "base permeability." Permeability is, in general, a dependent property and is influenced by grain size, moisture content and method of ramming. It is evident that variations in grain size will greatly affect the base permeability, and naturally the green permeability will be less than the base permeability, unless some peculiar situation exists.

Moisture content affects permeability in three general ways: (1) If less water is present than is needed to saturate the clay, *dry* clay particles may partially plug up the voids; (2) If the right amount of water is added, the clay will be saturated and stick to the silica grains, permitting maximum flow of air; (3) If too much water is present, the colloidal material swells and tends to fill voids, obstructing air flow. There are limiting values on moisture content to secure suitable green permeability. See Table IV. The data here are general, rather than indicating specifically that 9 or 10% of moisture must be present.

Permeability has already been defined and a method of expression given. The testing method may be briefly stated: The standard specimen is a cylinder, made by ramming the sand into a suitable mold with standard ramming conditions. The pipe (mold) containing the same is attached to an apparatus which will force a definite quantity of air through the specimen. The pressure of the air is read by a manometer, and the time noted with a stop watch. By use of suitable orifices, admitting the air to the sample, the permeability can be read direct from the calibrated manometer, and the time readings need not be taken.

Since no definite relationship has been shown to exist between dry permeability and green permeability, it is necessary to test sands in both conditions in which they may be used. The standard American Foundrymen's Association methods

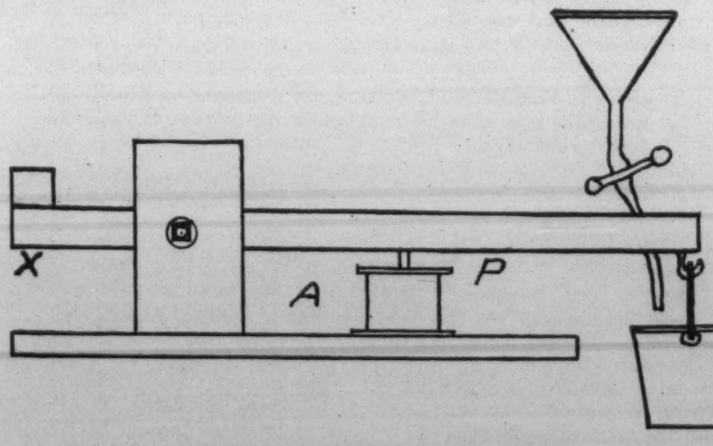

Fig. 7—Compression Test Machine

Diagram of type used in Molding Sand Research Laboratory of University of Cincinnati. Plate P is attached by means of swivel joint to the beam to prevent eccentric loading. A is an aluminum plate upon which the permeability test specimen has been placed after removal from cylinder.

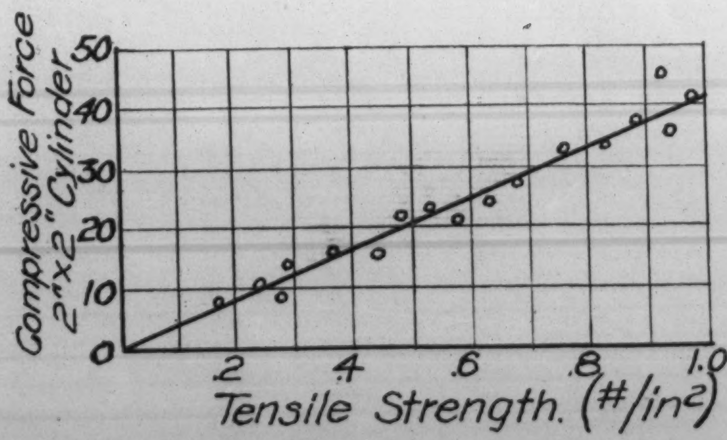

Fig. 9—Compression (Shearing) Values *vs.* Tensile Strength Values on a Number of Molding Sands. (Crane[3])

should be consulted and followed in making permeability tests. See Figs. 1, 2, 3, 4 and 10.

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[5] A. A. Grubb, "Molding Sand Reclamation and Control Experiments," *Transactions American Foundrymen's Association*, 32, Part 2, 5 (1924).

Refractoriness of Sand

The most important item in considering the refractoriness of a sand is the composition of the bond. Silica fuses at about 1600° C., and the addition of bond undoubtedly lowers its melting point. Molding sand fusion points vary with the minerals present. Since the pouring temperatures and actual temperature of the metal in the mold may be higher than the fusion points of the constituent minerals in the bond, it is important to avoid the use of sands which tests have shown will fuse under conditions of service. Mineralogical examination may identify and chemical analysis check the actual constituents. The situation, of course, is one of possible slag formation. Since acid anhydrides and basic anhydrides react at high temperatures to form compounds, and also since slag systems analogous to alloy systems exist, it is not difficult to understand why actual or incipient fusion of the sand is apt to occur below the fusion point of the silica, or even below the fusion point of some other constituent, as for example, in case the slag system is of the eutectic type.

Various methods of testing refractoriness have been proposed but cannot be discussed here in detail. One general method may be mentioned. Cones formed from finely divided material are fired at a uniform rate in a suitable furnace, and their softening temperature noted.

Durability of Sand

Numerous factors affect the "life" or durability of the sand. Chief of these factors are the quantity of bonding material, how it will stand heat and the heating conditions. When the bond is considered, it must be remembered that colloidal material is present and its ability to recombine with water after being dried out by heat is an important factor.

Various tests have been suggested, heating to 600° F. and comparing strength values with original strength, continuous use in a part of the foundry for a definite time period on a new sand, tests on the change in the nature of the colloidal material after heating by means of dye adsorption tests and others. This subject is still under investigation and no single method is as yet entirely satisfactory.

Table II—Comparison of Tests

Practical Man's Tests	Laboratory Tests	Tabulated Laboratory Data
1. Feels sand It is too dry, too wet or just right.	Moisture determination Bake weighed amount of sand and reweigh. $\frac{\text{Loss in weight}}{\text{Original weight}} \times 100 = \%\ H_2O$	See Tables IV and VIII
2. Squeezes handful of sand Breaks it to estimate strength.	Green strength determination A weighed amount of sand is rammed up in a definite sized mold, and the sand caused to break under its own weight or by other methods of tests.	See Tables IV and VIII
3. Squeezes handful of sand Puts to lips and blows through it.	Green permeability determination A cylinder 2" high and 2" in diameter is rammed up with a definite amount of ramming. A definite amount of air is drawn through and time and pressure noted. By using A. F. A. formula, permeability may be computed, or use a direct reading dial.	See Tables IV and VIII
4. Feels texture of sand Puts some sand in bottle with water, shakes well, vibrates, lets settle. Notes clay layer and fine and coarse silica. He is not justified in assuming all of the clay layer to be clay.	A. F. A. clay test A weighed amount of sand + sodium hydroxide + water is shaken for an hour in a mason jar. The water is siphoned off every 5 min. The silica is dried and weighed. Alternative methods may be used for more rapid determinations.	See Tables V, VI, VIII and IX.
5. Forms a cone of dry sand Makes a dry strength test by rubbing corner with thumb or scratch with file.	Strength test (use transverse test or compressive test) Ram a standard A. S. T. M. briquette. Pull in tension after baking at constant temperature.	See Tables IV and IX.

Table III—Comparison of the Conclusions Reached by the Practical Man with Those of the Laboratory

<table>
<tr><th>Noted by Practical Man in Making Tests Previously Described</th><th>Laboratory Test Data and Comments</th></tr>
<tr><td colspan="2">Green Sand Work</td></tr>
<tr><td>1. If sand is too dry or too wet, notes low green strength and low permeability.</td><td>Data in Table IV.
Compare moisture content with strength and permeability.</td></tr>
<tr><td colspan="2"><i>Sand too dry</i>, the following trouble may be expected: (<i>a</i>) cutting at corners and gates; (<i>b</i>) drop outs from cope; (<i>c</i>) bad pattern draws. There is not enough water to make clay 100% efficient.
<i>Sand too wet</i>, indicates probability of: (<i>a</i>) blows, kicks, misruns; (<i>b</i>) sagging of mold; (<i>c</i>) bad pattern draws. There is added weight and plasticity, and more steam is generated.</td></tr>
<tr><td>2. In breaking handful of sand, notes that it is too sharp or too coarse, thus indicating low green strength and coarseness of grain.</td><td>Data in Table V.
Compare clay percentages and screen percentages with moisture content constant and note variations in green strength and permeability.</td></tr>
<tr><td colspan="2">If the moisture content is correct, but the sand is too coarse or sharp, the following troubles may be expected: (<i>a</i>) cutting at sharp corners; (<i>b</i>) drop outs from cope; (<i>c</i>) roughened casting; (<i>d</i>) iron penetration.</td></tr>
<tr><td>3. In squeezing handful of sand and blowing through it, if sand is too sticky or too fine, notes low permeability but higher green strength.</td><td>Data in Table V.</td></tr>
<tr><td>4. The bottle test for clay is likely to be misleading.</td><td>Data in Table VI.
Weighed samples should be used and washing by some thorough method employed; followed by drying and weighing residue. Screen test following gives information of value in judging fineness.</td></tr>
<tr><td colspan="2">Dry Sand Work and Cores</td></tr>
<tr><td>1. If the sand is too dry, notes green strength is low.</td><td>Data in Table VII.
Note the effect of moisture on green strength, dry strength and dry permeability.</td></tr>
<tr><td colspan="2">Troubles to be expected from too dry sand: (<i>a</i>) dropouts in handling from ramming floors to ovens; (<i>b</i>) bad pattern draws: (<i>c</i>) low dry strength.</td></tr>
<tr><td>If the sand is too wet, notes green strength is low, but expects higher dry strength.</td><td></td></tr>
<tr><td colspan="2">Troubles to be expected from too wet sand include: (<i>a</i>) sagging in mold before reaching ovens; (<i>b</i>) mold or core to be rammed too hard, giving kicks, blows, misruns.</td></tr>
<tr><td>2. If the sand feels too sharp or too coarse, notes low green strength and coarseness of grain.</td><td>Data in Table IX.
Note the effect of clay and screen percentages on green strength, dry permeability and dry strength.</td></tr>
<tr><td colspan="2">Troubles to be expected include: (<i>a</i>) dropouts on handling; (<i>b</i>) lower dry strength; (<i>c</i>) roughened appearance of casting; (<i>d</i>) iron penetration.</td></tr>
<tr><td>3. If the sand feels too sticky, notes higher green strength and expects higher dry strength.</td><td>Data in Table IX.</td></tr>
<tr><td colspan="2">In this case, it can be expected that the mold or core will ram too hard, giving rise to kicks, blows, misruns and scabs. Testing for clay content is done in the same way as for green sand work.</td></tr>
<tr><td>4. Testing a baked core or mold by rubbing or breaking. If test is correctly made from viewpoint of all other factors and shows weak, then the sand may need more binder or vice versa.</td><td>Data in Table X.
All other factors held constant and amount of binder varied. Note differences in dry strength.</td></tr>
</table>

Comparison of the Tests Formerly Made by the Practical Man with Laboratory Tests

It should not be inferred from the foregoing title that laboratory tests are not practical. When the molder conditioned his own sand heap, he made certain practical tests, perhaps without realizing that he was testing the sand. These tests and observations enabled him to judge the suitability of the sand for the particular job. His methods of conditioning, and his judgment of the condition of the sand were based on experience. If a new sand came in, however, it might require some time and the loss of some castings to find out just how the sand should be treated.

The purpose of laboratory control of the sand heaps is to do away with the "guess work" as far as possible in conditioning the sand. Modern production methods do not permit the individual conditioning of sand heaps, and modern equipment calls for more exacting control of the sand. The following comparison will help to make the matter clearer.

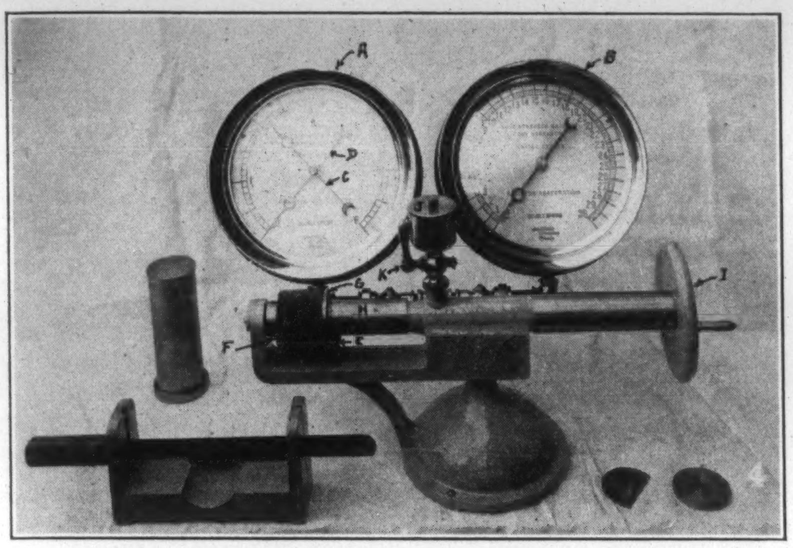

Fig. 10.—Device for Testing Strength of Molding and Core Sands by Shear (Dietert Design)

For green sand testing, a permeability specimen (see Fig. 1) is used. Pressure is applied through cylinder (H) on the specimen in holder (E). The moving head (G) is a half circular disc with the flat edge on the under side. The stationary head (F) is a half circular disc, with the flat edge uppermost. The pressure is indicated on gage (A) by pointer (C), (D) being the pointer which pushes (C) forward until the specimen ruptures, when (D) returns to zero. The oil cylinder is filled with oil through cup (J) when valve (K) is open. The rate of load application is described in the text under compression testing. For testing dry sand strengths, gage (B) is used.

Having compared practical tests with laboratory tests, we may consider the things a practical man notes as he feels the sand and tests it by other means, and compare the conclusions reached by this means with the conclusions reached through a consideration of laboratory data.

In considering the tests, it may be noted that there is no relation between green permeability and dry permeability.

Table IV—Data on the Variation of Green Strength and Green Permeability, with Variation in Moisture Percentage on a Sample of Molding Sand

Moisture	8.0%	9.0%	10.0%	11.0%
Green strength	181	200	195	178
Green permeability	32	45	48	36

Table V—The Variation in Green Strength and Green Permeability with Variation in Clay and Screen Percentages, Moisture Constant

Mesh	Sand No. 1	Sand No. 2	Sand No. 3	Sand No. 4
6	0.00	0.00	0.00	0.00
12	0.00	0.00	0.16	0.44
20	0.14	0.10	0.74	0.90
40	1.68	1.18	12.28	10.44
70	12.24	10.20	32.00	30.56
100	10.68	8.14	9.04	8.40
140	4.24	2.58	4.50	4.30
200	17.94	17.84	3.10	5.26
270	15.48	16.24	4.30	3.70
−270	21.94	23.86	16.32	11.42
Clay	15.68	19.86	17.52	23.68
Moisture	10.0%	10.0%	10.0%	10.0%
Green strength	154	171	175	186
Green permeability	20.1	15.0	51	34

Table VII—Data on the Variation of Dry Strenth, Dry Permeability and Green Strength with Moisture Content on a Typical Molding Sand

Moisture %	6.2	6.9	7.4	8.0
Green strength	157	160	160	138
Dry strength	14.2 lbs.	21.4 lbs.	23.1 lbs.	20.4 lbs.
Dry permeability	68.0	70.0	94.0	83.0

Table VI—Fineness Data and Clay Percentages on Several Sands

Mesh	Red Sand Very Sticky Clay Sand No. 5		New Lexington Sand Yellow Clay Sand No. 6		New Lexington Sand No. 7		Fine Core Sand Clay of Very Poor Quality Sand No. 8	
6	0.00		0.00		0.00		0.14	
12	0.04		0.16		0.00		0.22	
20	0.92		3.38		1.60		1.02	
40	21.20		31.19		34.94		7.34	
70	48.56		27.48		14.40		51.24	
100	5.34		4.11		2.52		18.09	
140	2.56		1.76		1.76		8.29	
200	2.14		4.31		1.90		7.99	
270	1.70	26.88	1.14	37.79	1.80	47.78	0.62	21.95
−270	2.86		8.18		15.40		1.22	
Clay	12.08		18.29		24.40		3.84	
Vibratory clay	42.5%		36.0%		44%		20%	

Table VIII—Comparison of Green Permeability and Dry Permeability Values on Several Samples of Molding Sand

	Green Permeability	Dry Permeability
Sample 1	131 A. F. A.	196 A. F. A.
Sample 2	136	157
Sample 3	136	173
Sample 4	137	210
Sample 5	139	174
Sample 6	157	202
Sample 7	98	168

Table IX—Data on Dry Sand Work

Mesh	Sample 1	Sample 2	Sample 3
6	0.00%	0.00%	0.00%
12	2.20	1.68	1.32
20	9.28	8.28	5.82
40	32.10	30.22	28.16
70	20.32	19.46	17.34
100	6.74	5.48	4.18
140	2.90	2.30	2.82
200	2.84	2.34	3.40
270	2.80	3.00	4.04
−270	5.60	6.66	9.02
Clay	15.50	20.40	24.00
Moisture, as rammed, before baking	8.0%	8.0%	8.0%
Green strength	134	171	195
Dry strength	21.3 lbs.	25.2 lbs.	28.74 lbs.
Dry permeability	69.0	66.0	55.0
Pitch compound binder	1.66%	1.66%	1.66%

Table X—Effect of Amount of Binder on Dry Strength, All Other Factors Maintained Constant

Core Mix	Binder	Dry Strength
47 parts Silica 3 parts Molding Sand	1 part	19.8 lbs.
47 parts Silica 3 parts Molding Sand	1½ parts	24.4 lbs.
47 parts Silica 3 parts Molding Sand	2 parts	71.0 lbs.

Summary

An attempt has been made to discuss the nature and occurrence of molding sands, to list and classify the variables connected with the properties of molding sand and to describe the usual tests applied to molding sands and indicate how results should be interpreted. No attempt has been made to describe details of testing methods or discuss the merits of proposed tests not adopted as standard.

Acknowledgment

During the years 1925-26, the Resource Survey of The University of Cincinnati and the Commercial Club of Cincinnati conducted researches on molding sands of the Cincinnati district, and in this connection investigated methods of testing. The author is particularly indebted to the unpublished thesis of Mr. P. W. Crane, who worked in this laboratory, for some of the information included in this article.

The foundrymen of the Cincinnati district have been of great assistance in furnishing data and information for this and other articles of the series. The author is particularly indebted to Mr. William Rengering, foundry engineer for the Cincinnati Milling Machine Company, for the comparison of tests made by the practical man with laboratory tests, and their interpretation.

Grateful acknowledgment is due the American Foundrymen's Association for supplying several illustrations which show sand testing equipment developed in the work of the joint Committee on Molding Sand Research.

The Effects of Silicon on the Properties of Brass[*]

By H. W. Gould[†] and K. W. Ray[‡]

Introduction

The effects of tin, aluminum, lead, manganese, iron and nickel on copper and brass are fairly well known. However, relatively little work seems to have been done on the effects of silicon on brass. It is stated[4] that 4% silicon added to ordinary yellow brass, with no lead present, gives very tough, ductile castings which are bright yellow in color and resemble manganese bronze in appearance. When the zinc content is increased to approximately 40%, the addition of 2% silicon produces similar effects, the tensile strength being quoted at 48,000 lbs./in.^{2}. The effects of silicon are similar to those of aluminum except that the alloy casts better and contains less dross.

Statement of Problem

A study was made of the effects of silicon on the properties of brasses. Such a study was thought advisable since very little work has been published in which the effects of silicon on brasses have been systematically studied. The purpose of the investigation was (1) to check any available data on the effects of silicon on the physical properties of brasses, (2) to determine the various properties over as great a range of compositions and as thoroughly as permitted in the time available for the study, and (3) to correlate these properties with the metallographic constituents of the same alloys.

Specific gravity, tensile strength, impact strength, percentage of elongation, hardness, resistance to corrosion and machinability were the properties studied.

Experimental Procedure

Three series of silicon brass samples were prepared, including ones containing no silicon. The copper-zinc ratios used were 85–15, 65–35 and 60–40. All samples were melted in five-inch clay crucibles in a small crucible furnace. The copper and silicon were first melted together; then zinc was added. Brasses which were to contain no silicon were never melted in a crucible to which any silicon had previously been added. Also the percentage of silicon was progressively increased in each succeeding melt. The flux cover used consisted of sodium chloride and borax in equal amounts.

Iron molds were used for all ingots, including the test bars. Ingots of two sizes were cast, the smaller 1 × 1 × 15 cm., the larger 1.1 × 1.1 × 15 cm. An iron mold was specially made for casting the test bars. The inside dimensions were 0.800″ in diam. ($^1/_2$ in.^{2} in cross section) and 12″ in length.

All samples were chill cast. In every case, the pouring temperatures were approximately 100° C. above the freezing point of the alloy. The mold was previously heated to 200–400° C. to prevent sputtering. The ingot was quenched in running tap water approximately one-half minute after being poured.

Specific Gravity

Specific gravity determinations were made on roughly polished samples 1$^1/_4$″ in length sawed from the large and small ingots. Each sample was weighed (1) in air, and (2) in distilled water by suspending it from a fine wire loop from the beam of the balance. From the weight in air and in water, the specific gravity was calculated. Redeterminations were made on samples which gave results too high or too low. In these cases, determinations were also made (1) of other samples from the same melt, and (2) of samples from different melts of approximately the same composition.

Hardness Tests

Hardness tests were made on each alloy which was cast. Three different hardness testing machines were used: (1) a Shore scleroscope, (2) a Rockwell hardness tester, and (3) a Baumann-Steinruck hardness tester. An attempt was also made to get Brinell hardness readings, but the values ob-

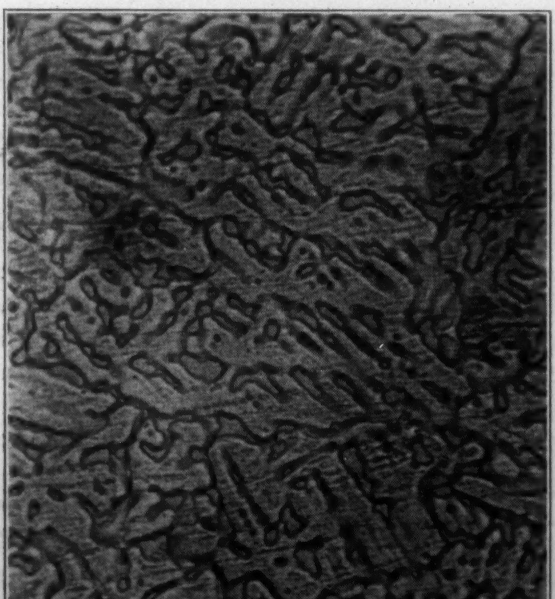

Fig. 4—Chill Cast. 82.5% Cu, 14.8% Zn, 2.7% Si. Magnification 300 Diam.

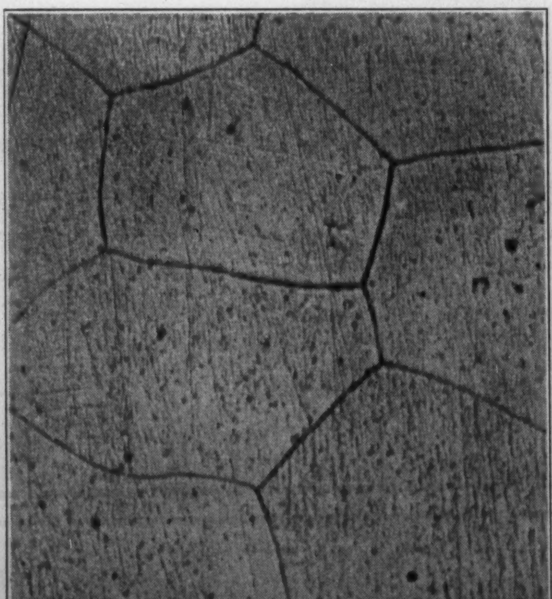

Fig. 5—Chill Cast, Followed by Annealing at 800° C. for 10 Hrs. Cu 83.3%, Zn 14.7%, Si 2.0%. Magnification 175 Diam. Homogeneous Alpha Phase

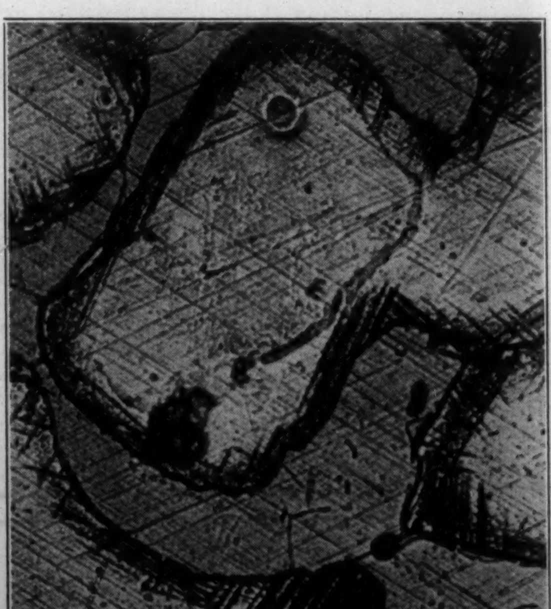

Fig. 6—Chill Cast, Followed by Annealing at 800° C. for 10 Hrs. Cu 82.1%, Zn 14.6%, Si 3.3%. Magnification 175 Diam. Alpha and Beta Phases

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[*] Concluding part of an article in two parts: for Part I see pages 455–457 of this publication, April.

[†] From a dissertation presented by Mr. Gould to the Graduate College of the State University of Iowa, August 14, 1929, in partial fulfillment for the PhD. degree.

[‡] Metallurgy Division of the Department of Chemistry, University of Iowa, Iowa City, Iowa.

[4] C. Vickers, *Foundry*, 38, 264–267 (1911).

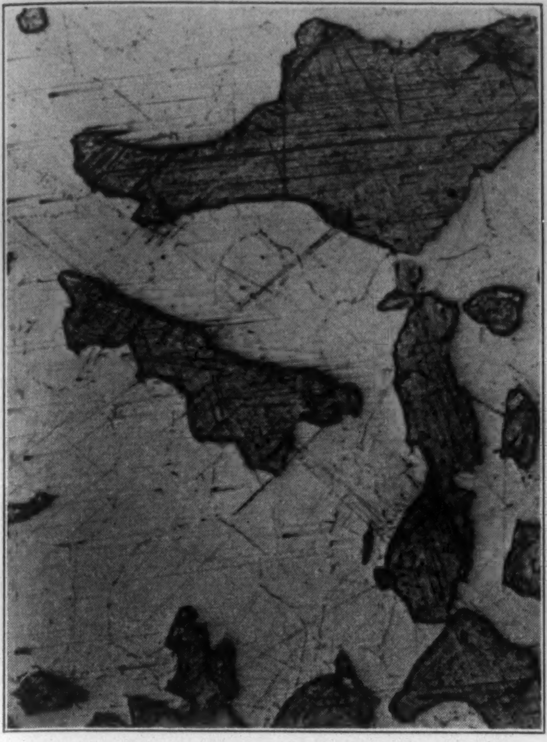

Fig. 7—Chill Cast, Followed by Annealing at 800° C. for 10 Hrs. Cu 81.2%, Zn 15.0%, Si 3.8%. Magnification 150 Diam. Alpha and Beta Phases, the Beta Continuous

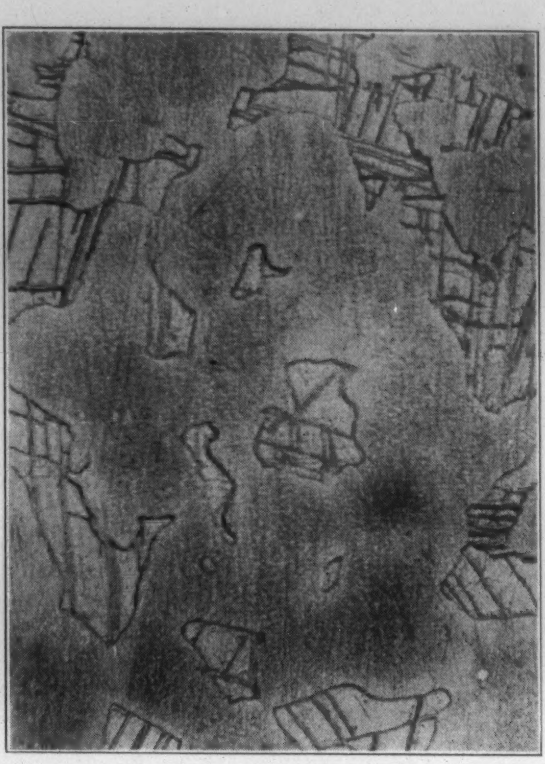

Fig. 8—Chill Cast, Then Annealed at 800° C. for 10 Hrs. and Quenched in Water. Slip Bands May Be Due to Quenching Strains. Cu 81.0%, Zn 14.5%, Si 4.5%. 300 Diam. Alpha and Beta Phases, the Beta Continuous

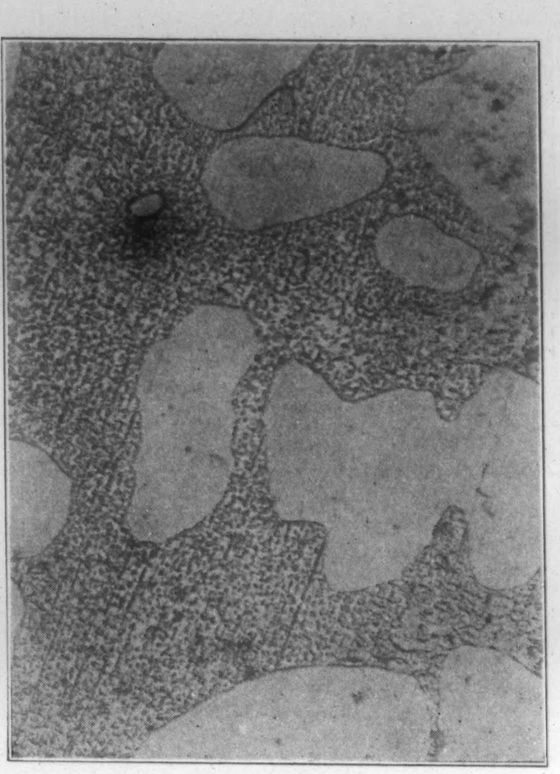

Fig. 9—Chill Cast, Then Annealed at 750° C. for 10 Hrs. Cu 80.4%, Zn 13.5%, Si 6.1%. 300 Diam. Etched by NH_4OH and H_2O_2. Beta and Gamma Phases, the Beta Continuous

tained were not dependable because the ingots were so small that they spread in many cases when a 3000 kg. load was applied. The 500 kg. load did not give dependable values for the harder specimens. Some of the samples were so brittle that the Rockwell and especially the Baumann test could not be used.

Impact Tests

A sample test bar 10 × 10 mm. × 2″ in length was cut from each small ingot, trimmed and polished very roughly. Each bar was given a 1 mm. notch, and tested in an impact machine of 100 ft.-lbs. capacity.[5] The machine was operated by measuring in foot pounds the work required to break or bend the specimen. The hammer weighed 33$^1/_3$ lbs., and fell as a pendulum 3 ft. The clearance between anvil and hammer was 1″.

Tensile Strength

A series of sample bars from the 85–15 series was poured and tested for breaking strength in lbs./in.² and for percentage of elongation (between the jaws of the machine). The machine used was a Tinius Olsen 50,000 lb. testing machine. Each bar was 0.800″ in diam. and 12″ in length. The bars were remelted and retested to get a second set of values. Except in the case of a flaw, the strength of the second bar was invariably greater than that of the first.

A series of bars for the 60–40 brass series was then prepared by melting up the twice-used bars of the former series and adding the necessary amount of zinc sticks to give a 60–40 ratio for the copper and zinc. The series also included bars obtained by melting up fresh metal.

The broken bars from the two series were tested for their machinability by an expert mechanician whose opinion was accepted as final.

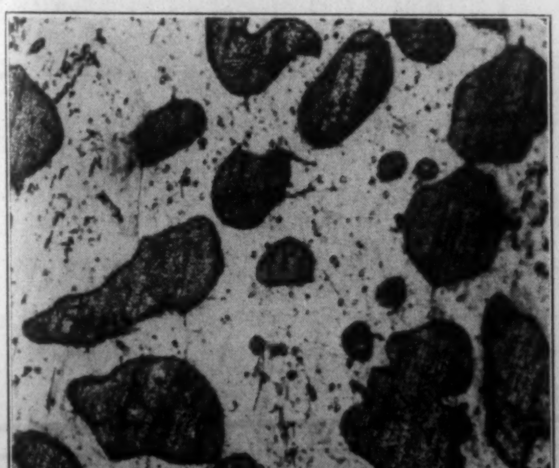

Fig. 10—Same as Fig. 8, Except Etched by HNO_3

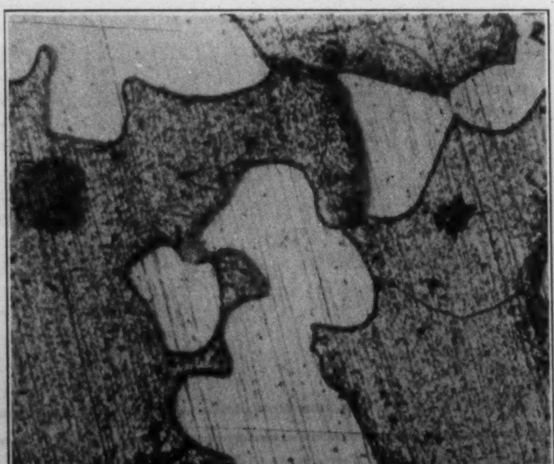

Fig. 11—Chill Cast and Annealed at 800° C. for 10 Hrs. Cu 63.7%, Zn 35.3%, Si 1.0%. 175 Diam. Alpha and Beta Phases, the Beta Phase Continuous

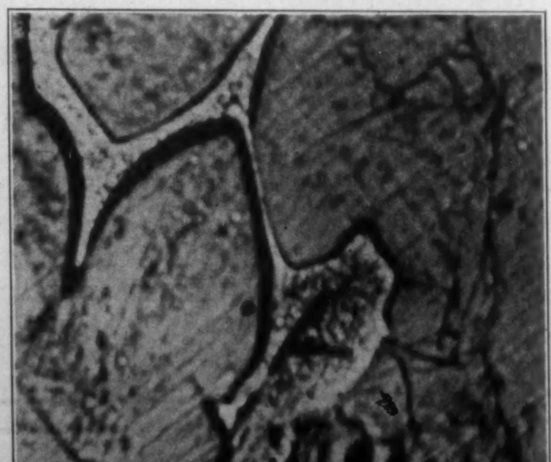

Fig. 12—Chill Cast and Annealed at 750° C. for 10 Hrs. Cu 58.8%, Zn 39.3%, Si 1.9%. 175 Diam. Alpha and Beta Phases, the Beta Continuous

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[5] Described by T. Y. Olsen, *Proceedings American Society of Testing Materials*, 11, 815–818 (1911).

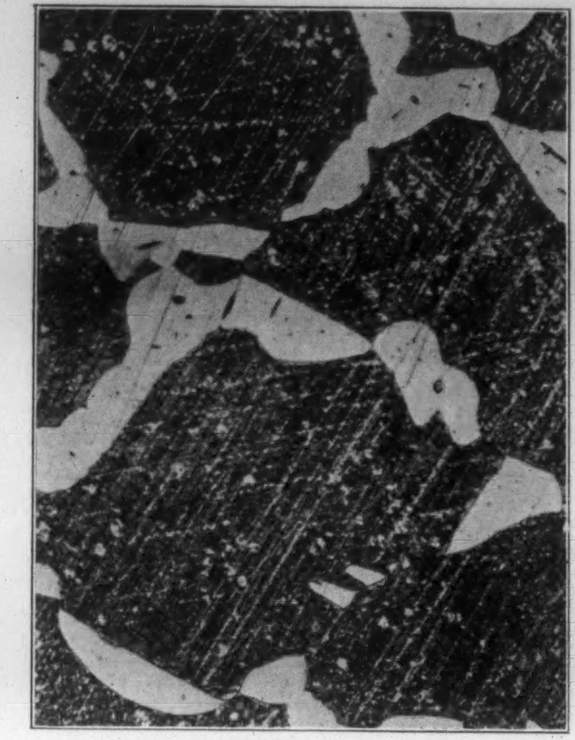

Fig. 13—Chill Cast and Annealed at 725° C. for 12 Hrs. Cu 57.8%, Zn 38.8%, Si 3.4%. 150 Diam. Beta and Gamma Phases, the Gamma Continuous

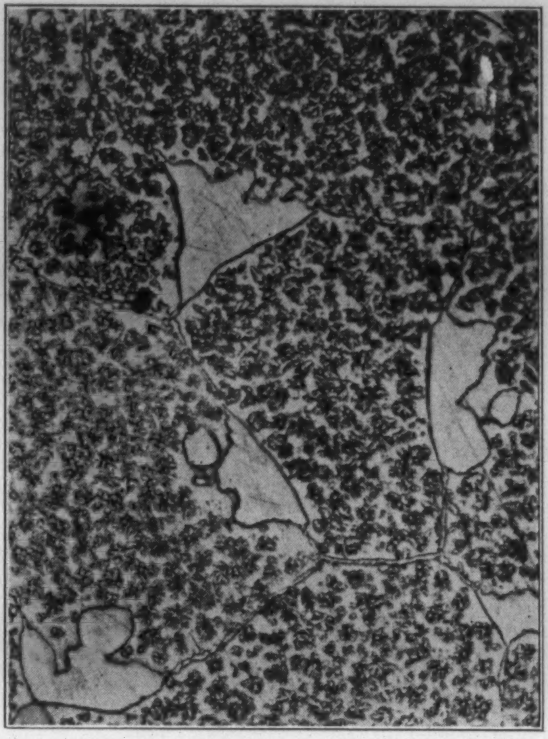

Fig. 14—Chill Cast and Annealed at 725° C. for 12 Hrs. Cu 57.8%, Zn 38.6%, Si 3.6%. 150 Diam. Beta and Gamma Phases, the Gamma Continuous

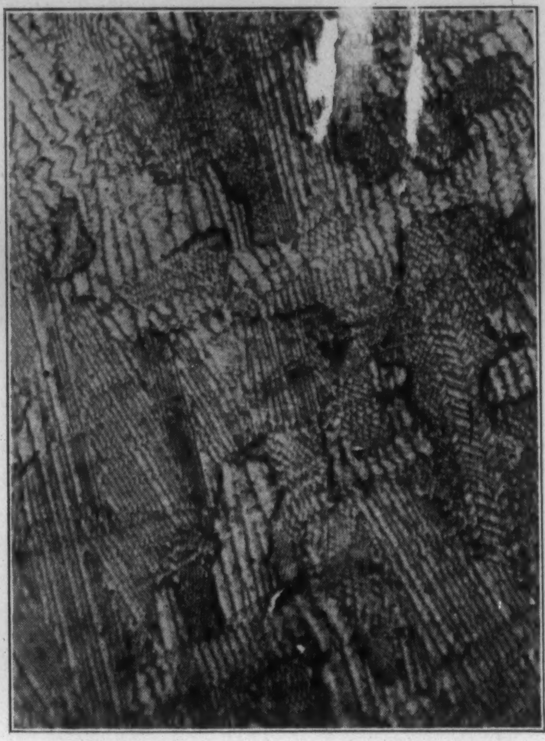

Fig. 15—Chill Cast and Annealed at 725° C. for 12 Hrs. Cu 57.5%, Zn 38.5%, Si 3.8%. 500 Diam. Probably a Pure Gamma Brass

Corrosion Tests

Samples selected from the 85–15 and 60–40 series of brasses were tested for corrosion resistance in various solutions. The tests included the following:

1. 1, 5, 10 and 30% sulphuric acid and sodium hydroxide solutions at room temperatures. Time 15–48 days.
2. 1 and 5% sulphuric acid and sodium hydroxide solutions. Boiling temperatures. Time 48 hours.
3. City Water (calcium and magnesium content 125 parts per million). Room temperatures. Time 11½ months.
4. Sodium chloride solutions (10% and saturated). Room temperatures. Time 11½ months.
5. Magnesium sulphate solutions (10% and saturated with respect to the anhydrous salt). Room temperatures. Time 11½ months.
6. Calcium sulphate solution (saturated). Room temperatures. Time 11½ months.

The silicon contents were: 0, 2.1, 3.9 and 6.7% for the 85–15 series (sulphuric acid and sodium hydroxide solutions).

0, 2.1, 2.7 and 5.1% for the 85–15 series (other solutions).

0, 0.8, 2.7 and 2.8% for the 60–40 series (sulphuric acid and sodium hydroxide solutions).

0, 0.8, 1.1 and 2.7% for the 60–40 series (other solutions).

All tests made were immersion tests in which samples of fairly uniform size and dimensions were plane-ground and rough-polished, cleaned, weighed and immersed in 250 cc. beakers containing 100 cc. of the corrosive solutions. The percentage loss in weight was taken as the chief index on the corrosion of samples. That such an index is inadequate in many respects was well recognized. Subsequent tests showed, for instance, that a sample might very closely maintain its original weight and yet be subject to considerable corrosion. Nevertheless, such an index proved to be the most generally satisfactory for the investigation. Methods for removing protective coatings before weighing samples did not work successfully. Therefore, no attempt was made to dissolve off any surface coating or to brush off more than any loosely adhering particles. Frequent note was made of the surface appearance of each sample.

Data and Discussion

Specific Gravity Data

Fig. 16 indicates the effect of added silicon on the specific gravity of a brass. Aside from three or four irregularities, which are probably due to poorly mixed or melted metal, the specific gravity is seen to be regularly decreased by the addition of silicon. Increased zinc content, of course, also lowers the specific gravity.

Table III compares the actual values for the specific gravity of these alloys with their calculated values. It is seen that the first addition of silicon causes a slight shrinkage, and that larger amounts cause expansion. That is, the specific gravity is slightly higher than the calculated value for the low-silicon alloys, and is slightly lower than the calculated value for the intermediate alloys. For high-silicon alloys, the specific gravity is considerably lower than the calculated values, due, for the most part, to the open, porous structure. The former case is in harmony with the fine, compact, close-grained structure of the alpha solid solution brasses.

Table III—Specific Gravity of Silicon Brasses

85–15 Brass			65–35 Brass			60–40 Brass		
% Si	Sp. Gr. Calcd.*	Sp. Gr. Found	% Si	Sp. Gr. Calcd.*	Sp. Gr. Found	% Si	Sp. Gr. Calcd.*	Sp. Gr. Found
0.0	8.63	8.72	0.0	8.40	8.48	0.0	8.30	8.40
0.9	8.57	8.58	1.1	8.25	8.34	0.8	8.14	8.20
2.1	8.51	8.42	1.3	8.22	8.30	1.1	8.12	8.08
2.4	8.48	8.47	2.0	8.19	8.26	2.7	8.03	8.10
2.8	8.45	8.30	2.7	8.15	8.13	2.8	8.02	7.78
3.3	8.43	8.10	4.2	8.05	7.93	4.2	7.94	7.62
3.9	8.39	8.26	4.5	8.03	7.43	7.0	7.80	7.08
5.1	8.33	8.08	5.0	8.01	7.65			
6.0	8.23	7.71	5.9	7.95	7.34			
6.7	8.31	7.88	6.1	7.94	7.30			
8.6	8.10	7.35	6.8	7.90	6.60			
9.5	8.04	8.39						
10.8	7.97	7.13						

* Calculations are based on values of 8.90, 7.10 and 2.42 for specific gravities of copper (as cast), zinc (as cast) and crystalline silicon respectively.

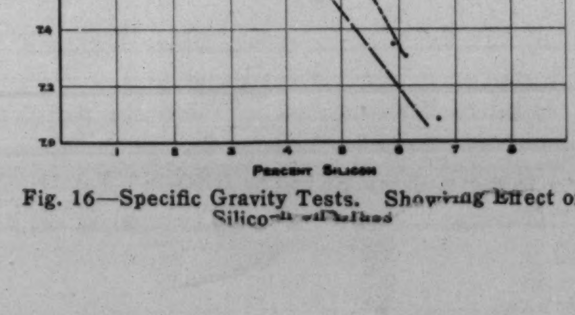

Fig. 16—Specific Gravity Tests. Showing Effect of Silicon on Brass

Impact Breaking Strength

Table IV shows that silicon increases the breaking strength for the 85–15 [illegible] the 65–35 brass series, but not for the 60–40 series unless at very low percentages. The maximum impact breaking strengths for the three series of brasses are approximately:

85–15 brass—3.3% silicon—(81 ft.-lbs.)
64–35 brass—1.3% silicon—(92 ft.-lbs.)
60–40 brass—0.0% silicon—(95 ft.-lbs.) (bent)

By comparing the four series (including 70–30 brass with no silicon), it is seen that zinc has a strengthening effect from 15–40%, where silicon is not present.

Table IV—Impact Breaking Strength (in Ft.-Lbs.)

85–15 Brass			65–35 Brass			60–40 Brass		
% Si	Impact		% Si	Impact		% Si	Impact	
0.0	bent	81°*	0.0	bent	70°*	0.0	bent	95 ft.-lbs. (approx.)
0.9	bent	76°*	1.1	broke	64 ft.-lbs	0.8	broke	21 ft.-lbs.
2.1	bent	..	1.3	broke	92 ft.-lbs.	1.1	broke	14 ft.-lbs.
2.4	bent	57°*	2.0	broke	37 ft.-lbs.	2.7	broke	6 ft.-lbs.
2.8	broke	62 ft.-lbs.	2.7	broke	7 ft.-lbs.	2.8	broke	0 ft.-lbs.
3.3	broke	81 ft.-lbs.	4.2	broke	0 ft.-lbs.	4.2	broke	0 ft.-lbs.
3.9	bent	27.5°*	4.5	broke	0 ft.-lbs.	6.7	broke	0 ft.-lbs.
5.1	broke	48 ft.-lbs.	5.0	broke	0 ft.-lbs.			
6.0	broke	3 ft.-lbs.	5.9	broke	0 ft.-lbs.			
6.7	broke	0 ft.-lbs.	6.1	broke	0 ft.-lbs.			
8.6	broke	0 ft.-lbs.	6.8	broke	0 ft.-lbs.			
9.5	broke	0 ft.-lbs.						
10.8	broke	0 ft.-lbs.						

* Reading is the number of degrees through which the bar is bent

70–30 Brass (no silicon) broke, giving a reading of 80 ft.-lbs.

All three of the above brasses showing maximum impact breaking strength are mixed alpha and beta brasses with the alpha phase continuous. Evidently, the appearance of the beta solid phase decreases the impact breaking strength of the alloy. At least the strength falls to practically zero on or before the point at which the beta solid phase becomes continuous.

Hardness Tests

The hardening effect of silicon on the above three brass series is shown in Fig. 17. It is seen that, for all three series, the hardness increases fairly rapidly to a near maximum at a point at which the alloy is decidedly brittle. Beyond this point, the curve flattens out, at about 7–9% silicon, indicating that maximum hardness is practically attained for the highest silicon alloys tested. The turning point in the curve (marking the beginning of decided brittleness) is somewhat sharper for the 85–15 brass than for the other series containing more zinc.

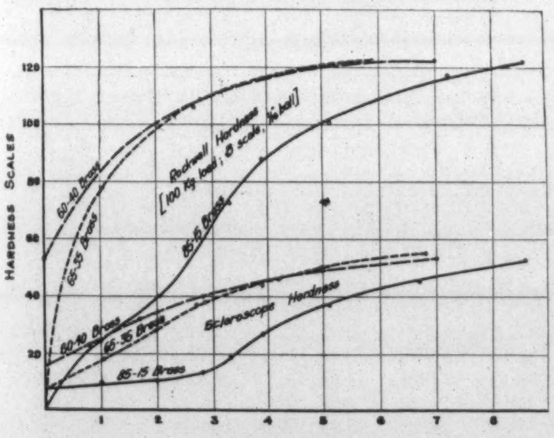

Fig. 17—Hardness Tests. Showing Effect of Silicon on Brass

By comparing the corresponding points on the three graphs representing no silicon, the relative hardening effects of increasing amounts of zinc may be noted.

Tensile Strength, Percentage Elongation and Hardness of Test Bars

Figs. 18 and 19 show the further effects of varying percentages of silicon on other physical properties of 85–15 and 60–40 brass. The tensile strength of an 85–15 brass is increased markedly up to approximately 4.5% silicon, beyond which it is rapidly decreased as the brittle point is reached, showing the formation of gamma solid phase. For a 60–40 brass, maximum strength is reached at about 1.0% silicon, although samples containing slightly less than 2.0% silicon are still stronger than the pure brass containing no silicon.

The percentage elongation increases markedly to a maximum of 38% at 1.5% silicon for the 85–15 brass, and also increases to a maximum at about 1.0% silicon for the 60–40 brass. It should be noted that for the 85–15 brass series, the percentage elongation for a silicon brass of maximum strength is still 10%. Variation in silicon content has little effect on the percentage elongation between 2.5 and 4.5% silicon. But beyond 4.5% silicon, both tensile strength and percentage elongation decrease rapidly. It should also be noted that for the 60–40 series the tensile strength reaches a maximum at about 1.5% silicon, and the percentage elongation at about 1.0% silicon. Both decrease very rapidly to practically zero at slightly higher percentages, the tensile strength at 2.0% silicon and the percentage elongation at about 1.5%.

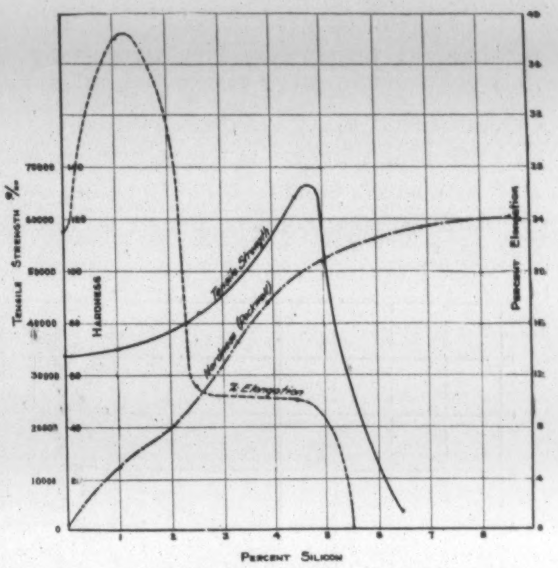

Fig. 18—Graph Showing Effect of Silicon on 85-15 Brass (2nd Heat)

In most cases, the tensile strength and percentage elongation decrease more rapidly beyond the maximum point than they increase before reaching it. It is, therefore, better to put slightly too little silicon into an alloy than slightly too much.

The hardness values were determined on the test bars to show the relation to tensile strength and percentage elongation. The curves for hardness show that maximum hardness is reached at about 9% silicon for the 85–15 brass series, and at about 7% silicon for the 60–40 brass series. The hardness increases more rapidly for the 60–40 series than for the 85–15 series. For the former, the increase in hardness is most rapid between 2 and 4% silicon.

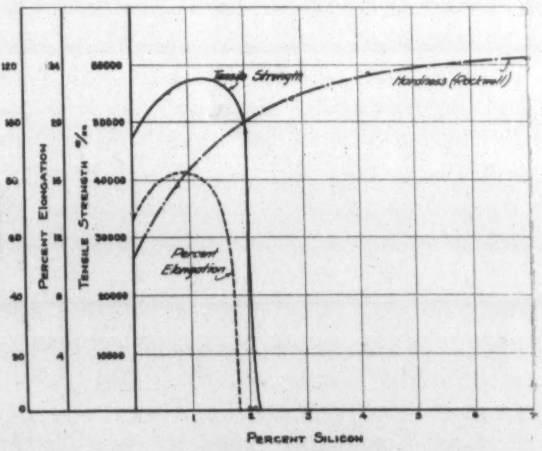

Fig. 19—Graph Showing Effect of Silicon on 60-40 Brass (2nd Heat)

The machinability of the various samples studied should be mentioned in connection with the above tests. 85–15 brass containing less than 5% silicon, also 60–40 brass containing less than 2% silicon, can be sawed, drilled and threaded. These brasses can be readily machined at high speed. Brasses containing somewhat higher percentages of silicon are difficult to saw or drill. 7 and 3% silicon, for the 85–15 and 60–40 series respectively, produce alloys that are too brittle to be readily shaped in any way except with an abrasive wheel.

Corrosion Tests

The results from the corrosion tests are in many cases very erratic, and as a whole are hard to interpret. Many inconsistencies are apparent, as might be expected, in view of the many factors entering into corrosion, not all of which were controlled. Figs. 20, 21, 22, and 23 are fair representatives of the behavior of the alloys with respect to percentage loss in weight. Based on percentage loss in weight and on the surface appearance of the samples, the following generalizations seem justified:

1. Silicon, in percentages lying within the range of good mechanical properties, has apparently little effect on the corrosion resistance of 85–15 and 60–40 brass. There is some evidence that a 2.1% silicon sample of the 85–15 brass series (a pure alpha brass) is slightly more resistant to corrosion. In many cases, silicon seems to cause the formation of a gray or black surface coating which serves to check subsequent corrosion.

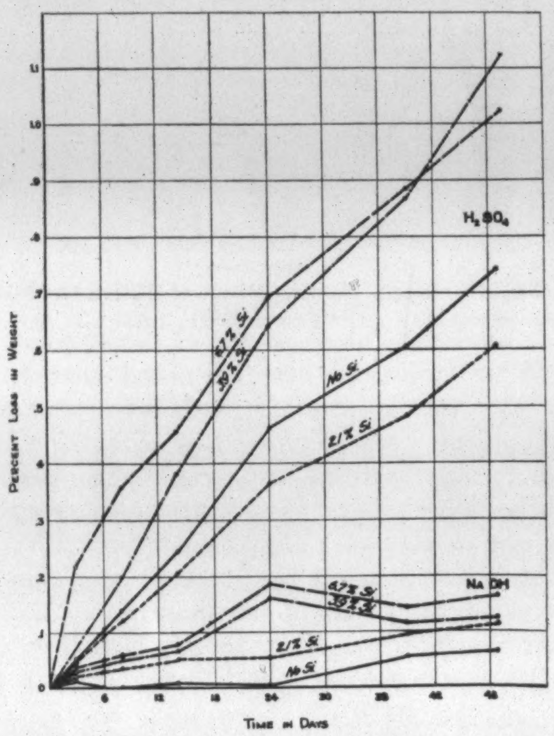

Fig. 20—Corrosion Tests. 85-15 Brass in 10% Sulphuric Acid Solution, also in 10% Sodium Hydroxide Solution

2. Where silicon is present in amounts sufficient to cause an open, porous structure, the rate of corrosion is markedly increased.

Referring to the previous work on the constitution of brasses, the following correlations are important:

(1) *For the 85–15 Brass Series*—The 1.5% silicon brass of maximum percentage elongation is a pure alpha solid solution brass. The 4.5% silicon brass of maximum tensile strength is a mixed alpha and beta brass with about equal quantities of the two phases present. This maximum probably also marks the point at which the alpha phase first becomes discontinuous. It is significant also that the rate of increase in hardness is greatest at about this point. The percentage elongation varies very little between the appearance of the beta solid phase (about 3.0% silicon) and the point at which this phase first becomes continuous (about 4.5% silicon). Beyond this point, both tensile strength and percentage elongation rapidly decrease until they are both practically zero soon after the disappearance of the alpha phase and the appearance of the gamma phase (at about 6.5% silicon). There may or may not be a pure beta solid solution brass in this interval. The maximum hardness is practically reached for a pure gamma brass at about 8.6% silicon.

Table V—Hardness Tests

85–15 Brass			65–35 Brass			60–40 Brass		
% Si	Rockwell	Scleroscope	% Si	Rockwell	Scleroscope	% Si	Rockwell	Scleroscope
0.0	−10	8	0.0	15	8	0.0	53	16
0.9	25	10	1.1	78	18	0.8	79	23
2.1	40	11	1.3	85	20	1.1	84	25
2.4	52	13	2.0	98	28	2.7	106	39
2.8	57	14	2.7	109	38	2.8	109	40
3.3	73	20	4.2	...	45	4.2	117	46
3.9	88	27	4.2	117	44	7.0	122	53
5.1	100	37	5.0	120	50			
6.0	112	42	6.1	122	58			
6.7	117	45	5.9	122	56			
8.6	121	53	6.8	...	55			
9.4	...	56						
10.8	122	58						

(Rockwell hardness; 100 kg. load, B scale, 1/16" ball.)

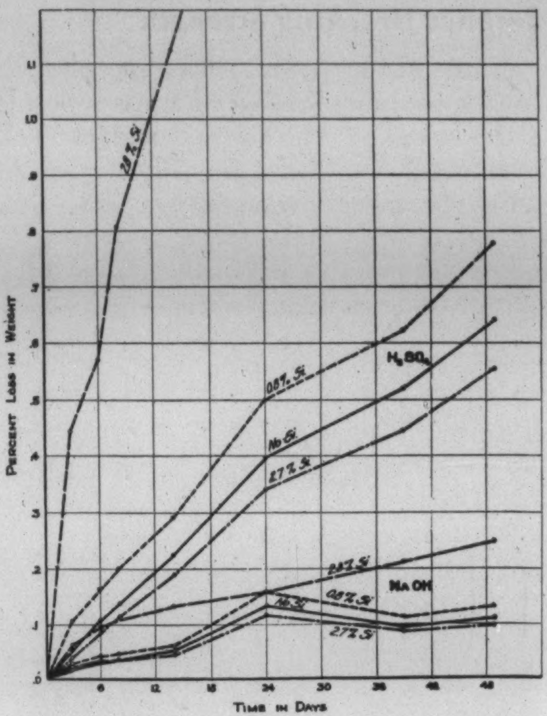

Fig. 21—Corrosion Tests. 60-40 Brass in 10% Sulphuric Acid Solution, also in 10% Sodium Hydroxide Solution

(2) *For the 60–40 Brass Series*—The alloys of this series are never composed of pure alpha solid solutions, due to the higher ratio of zinc to copper. The 1.0% silicon brass of maximum percentage elongation is a mixed alpha and beta brass. This silicon content closely marks the point at which the alpha phase becomes discontinuous. Maximum tensile strength is also reached soon after this point. Both percentage elongation and tensile strength decrease to practically zero on or before the appearance of the gamma solid phase (between 2 and 2.7% silicon). Maximum hardness is approached for a pure gamma brass at about 4.2% silicon.

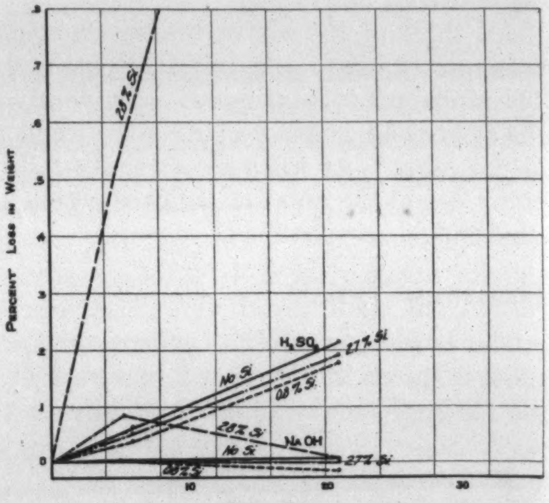

Fig. 22—Corrosion Tests. 60-40 Brass in 30% Sulphuric Acid Solution, also in 30% Sodium Hydroxide Solution

For both series, it is evident that the best brasses, with respect both to tensile strength and percentage elongation or toughness, are mixed alpha and beta alloys with the alpha phase continuous.

Table VI—Tensile Strength, % Elongation

85–15 Brass					60–40 Brass			
	1st Heat		2nd Heat			1st Heat		2nd Heat	
% Si	% Elong.	lbs./in.²	% Elong.	lbs./in.²	% Si	% Elong.	lbs./in.²	% Elong.	lbs./in.²
0.0	22.9	29,130	17.0*	26,540*	0.0	7.3	40,400	13.5	47,360
1.1	24.0	30,400	38.0	35,500	0.6	11.8	50,280	16.4	55,220
2.7	8.3	39,340	11.3	42,000	2.0	0.0	26,620	0.0	33,000
4.5	6.9*	56,760*	10.1	64,080	2.1	0.0	30,260	0.0	48,120
6.5	0.0	2,000	0.0	3,560	3.0	0.0	brittle	0.0	brittle
					4.5	0.0	brittle	0.0	brittle

* Flaw.

All bars containing silicon in amounts insufficient to cause brittleness showed a fine, compact, close-grained structure at the break. Bars containing higher percentages of silicon showed a coarser or a large crystalline structure.

Summary and Conclusions

1. Tests for specific gravity, hardness, impact breaking strength, tensile strength, percentage elongation and corrosion resistance were made on a series of brasses containing varying percentages of silicon.

2. The specific gravity of a brass is uniformly decreased by increasing percentages of silicon.

3. The hardness of brass is rapidly increased by silicon until a maximum is practically reached at 9% silicon for the 85–15 brass, and at 7% silicon for the 65–35 and 60–40 brasses.

4. An 85–15 brass begins to become brittle at about 6%

silicon, a 65–35 brass at 3% silicon and a 60–40 brass at about 2% silicon.

5. The tensile strength increases to a maximum at about 4.5% silicon for 85–15 brass, and at about 1.5% silicon for 60–40 brass.
6. The impact breaking strength is greatest at about 3.3% silicon for 85–15 brass, at about 1.3% silicon for 65–35 brass and at less than 0.8% silicon for 60–40 brass.
7. The percentage elongation for 85–15 brass is markedly increased by silicon to a maximum at about 1.5% silicon; the maximum for 60–40 brass is reached at about 1.0% silicon.
8. The decrease in both tensile strength and percentage elongation is very rapid after the maximum value is exceeded.
9. Small percentages of silicon produce a very fine, compact structure in brasses.
10. Brasses containing silicon are much more easily cast than those not containing silicon. The ingots are clear and of a much better appearance.
11. 2 to 5% silicon in 85–15 brass and 1 to 3 silicon in 60–40 brass produce a beautiful gold yellow to silver gray color. Higher percentages of silicon in both series produce a dull slate-gray color. The structure is usually open and porous for the high-silicon alloys.
12. 85–12 brass containing less than 5% silicon, also 60–40 brass containing less than 2% silicon, can be sawed, drilled and threaded. These brasses can be readily machined at high speed.
13. Silicon has little effect in general on the corrosion resistance of 85–15 and 60–40 brasses, except when it is present in amounts sufficient to give an open, porous structure, in which case the rate of corrosion is increased.
14. Most of the silicon brasses are modified by heat treatment.
15. Silicon may be used in brasses where strength, hardness and toughness are required, provided that lead and aluminum are absent.

Minor Alkali Metals Have Various Odd Uses

Metals soft enough to be cut with a knife and which decompose water at ordinary temperatures form the subject of a study of the minor or rarer alkali metals just completed by the United States Bureau of Mines, Department of Commerce. Of the group, caesium and rubidium ignite spontaneously if placed in dry oxygen at room temperature, and therefore must be kept in a vacuum.

Caesium, rubidium and lithium generally occur together in nature, although lithium is distributed more widely and is far more abundant than either of the other two, says R. M. Santmyers, mineral specialist, in a report made public by the Bureau of Mines. The chemical, and even the physical, properties of these three elements can best be considered in conjunction with the more familiar members of the alkali group, sodium and potassium. All five elements are silvery white and tarnish rapidly in air. All are exceptionally light, lithium being only a little more than half as heavy as water and being the lightest element solid at ordinary temperatures.

Had it not been for the spectroscope, the discovery of the elements caesium and rubidium would doubtless have been long postponed. In 1846 C. F. Plattner analyzed the mineral pollucite from the island of Elba and was mystified by the fact that the constituents apparently totaled only 92.75%. Careful search failed to reveal any error in analysis or any constituents that had been overlooked, and the problem remained unsolved until 1860, when caesium was discovered. In 1864, four years after the discovery of caesium, Pisani repeated the analysis of pollucite and found that the alkali metal Plattner had called potassium was in reality caesium. When corrections were made for the differences in atomic weights of caesium and potassium Plattner's results were found to be quite accurate.

In 1860 Bunsen used the newly devised spectroscope to examine the mineral constituents of the spring water at Durkheim, and discovered two blue lines of unknown origin. He became convinced that they were characteristic of a new alkali metal and proposed the name caesium from the Greek for "sky blue." Forty tons of water were evaporated in order to get enough caesium salts for experiments.

Caesium was the first element discovered by the use of the spectroscope, and a year later (in 1861) rubidium was discovered by the same means. Bunsen and Kirchhoff were then studying the alkaline constituents extracted from samples of lepidolite from Saxony and found that the chloroplatinate precipitate contained a salt somewhat less soluble than the potassium salt and whose spectrum had new lines in the violet, blue, green, yellow and red. Especially prominent were two red lines lying beyond Fraunhofer's line in the outermost portion of the red solar spectrum, hence the name rubidium, "dark red," was suggested for this new element. Such small amounts were present in the mineral with which Bunsen and Kirchhoff were working that they used 150 kg. to obtain enough of the new element to permit a study of its properties.

Lithium had been isolated some years before caesium and rubidium were found and was discovered by Aug. Arfvedson. While working in Berzelius' laboratory in 1817, he found a new element in the minerals petalite and spodumene and named it lithium, meaning "stony," in contrast to sodium and potassium, which are widely distributed in plants and animals. This element differed from the known alkali metals in the insolubility of its carbonate, the hygroscopic nature of its chloride and the low melting points of the chloride and sulphate.

Later work of Bunsen and Kirchhoff with the spectroscope showed that lithium was also distributed very generally in animal and plant tissues, although usually in extremely small quantities.

Although the minerals from which caesium, rubidium and lithium may be extracted are distributed rather widely in nature, the known minerals and deposits rich enough to furnish large supplies are few. Most of the minerals contain at least a trace of all three elements. Several minerals comparatively rich in lithium are known, but only one (pollucite) is high in caesium, and no definite rubidium minerals are known. Lepidolite, the best known of the lithium minerals in a number of localities carries from a trace to more than 3% of rubidium oxide, and a small fraction of a percent of caesium oxide. Lepidolite, in fact, carries more rubidium than any other known mineral, although on very incomplete data a tiny specimen of a rubidium mineral, rhodozite, from the Urals has been described. The principal lithium minerals are lepidolite, amblygonite and spodumene.

Caesium and rubidium appear on the market as salts, mainly chlorides, nitrates and hydroxides, and only rarely in their metallic state.

There has been little demand for caesium. The principal use at present is in the manufacture of radio tubes. The caesium is introduced into the tubes in the form of chloride, mixed with magnesium or calcium, and is compressed into small tablets or "pills;" at one stage in the manufacture of the tube the pill is flashed, eliminating the last trace of air and thus securing the desired vacuum. The caesium chloride supplies positive ions at the surface of the filament.

Both caesium and rubidium are employed to a limited extent in the manufacture of photo-electric cells. Rubidium, however, appears to be more suitable for this than caesium, because an extremely thin layer can be applied on the inner side of the glass. In the manufacture of these cells the metal, either caesium or rubidium, is introduced in excess but later is removed entirely except for the molecular layer that has formed on the silver or other base-metal electrode. The photo-emission of the molecular layer of metal is greater than that of the massive metal.

Rubidium compounds are employed in larger amounts than the metal because they have proved their importance as reagents in microchemistry; their ability to form crystalline compounds readily makes them of great value in this important and rapidly developing field.

Unlike caesium and rubidium, lithium minerals are used both as they occur in nature and as sources of lithium salts and compounds. One of the earliest uses for lithium salts was in the manufacture of lithia water and other medicinal preparations, but the use of lithia water has declined rapidly in recent years. The carbonate, phosphate, nitrate and organic compounds are used for medicinal purposes.

At present the largest use for lepidolite is in the manufacture of opal glass. It is ground and added, either fused or unfused, to the glass batch. Lepidolite to be used in glass-making must be free from tourmaline and other possible coloring materials. Patents cover the use of the mineral for this purpose.

In pyrotechnics, lithium chloride is used to impart a crimson color to fireworks and signal lights. Fairly large quantities of several of the compounds of lithium are used in other ways. For example lithium hydroxide is used in alkaline electrolyte storage batteries, lithium bromide and iodide are employed in photography, and lithium carbide is used in Roentgen-ray experiments.

(*Continued on page 536*)

Industrial Heating for Heat Treatment

By Robert M. Keeney*

> ***Much bull is thrown by furnace manufacturers and proponents of one type of fuel or another, in regard to the wonderful results shown by their furnace or their fuel in heat-treatment. We could readily fill many pages of this journal with papers of this nature written by authors with an axe to grind. Often it is true that the particular furnace described or the particular application of fuel or electricity cited does represent an advance, But if a similar application of sound engineering principles were made to other furnaces and other fuels, they, too, might show improvement.***
>
> ***It is far more important to discuss the principles on which all successful heat-treatment furnace design and utilization rests than to discuss individual applications. Most of the fundamentals are known, but they are too seldom appreciated. This article and the one to follow should aid in their appreciation.***

Fundamentals

Heat treatment is an operation, or combination of operations, involving the heating and cooling of a metal or an alloy in the solid state for the purpose of obtaining certain desirable conditions or properties. The problem in heating and cooling for heat treatment is one of quality production at a low over-all cost of finished product.

Quality depends upon the production of a uniformly heated and uniformly cooled product in a suitable heating or cooling atmosphere. A uniformly heated product involves:

(1) The application of heat uniformly to the entire surface of the charge.
(2) Heating the charge at the proper rate to the correct temperature as indicated by the critical point of the metal or alloy and by the properties desired.
(3) Holding the charge at the correct temperature for the period of time necessary for complete saturation as determined by the surface exposed, the mass to be heated, the conductivity of the material, and the grain structure desired.

Thus, a uniformly heated product involves not only the correct temperature, but the rate of heating, the time held at this temperature, and the uniform application of heat to the charge. It involves not simply the production of one uniformly heated piece, but production of thousands of pieces which must all be heated individually to the same temperature, at the same rate, for the same time, in the same atmosphere, with the same method of heat application in order to obtain a uniformly heated product. It is such a difficult problem that absolute uniformity is rarely obtained.

To attain that essential of quality production—a uniformly heated product—suitable equipment and methods must be employed.

(1) A uniformly heated furnace chamber designed so as to result in uniform application of heat to the charge.
(2) Temperature control equipment of such a nature as to prevent heating the charge above the desired temperature.
(3) Skilled metallurgical supervision to determine the correct rate of heating, the correct temperature, the period of holding at this temperature and the proper method of charging, distribution of product in the furnace, and method of discharging.

    Temperature control is important but it is only one part of the combination of conditions necessary to the production of a uniformly heated product, and cannot replace skilled supervision. The form of furnace with reference to uniformity of heat application to the charge is of the greatest importance. It is probably of more importance than the source of heat in the production of a uniformly heated product. Insofar as the production of a uniformly heated product is concerned, the source of heat must be considered as secondary to the form of furnace and to skilled supervision. With the form of furnace determined, the selection of the source of heat depends upon its care of application to the form of furnace, with reference to control of liberation of heat, control of temperature and control of atmosphere, and upon its ultimate effect on the over-all cost of the finished product. It is not a problem of B. t. u. costs but an economic problem of over-all costs.

Quality production at a low over-all cost when put in practice becomes relative. The quality required in a drop forging is not the quality required in the die with which it is forged and to maintain balance, the equipment of the source of heat should be selected with due consideration to the grade of product desired. A Rolls-Royce cannot be used for work which can be done by a Ford, without an unnecessary increase of over-all costs. Quality and cost must often compromise. The follow items influence over-all costs:

Direct	Indirect
Fuel	Quality and rejections
Compressed air-steam	Finishing of product
Electricity	Labor after heat treatment
Labor for heat treatment	Handling and cartage
Maintenance of furnaces	Capital charges on material in storage and in process
Capital charges on furnace and accessary equipment	Ease of operation
	Working conditions

Uniformity of Heat Application

To obtain a uniformly heated product a uniform chamber temperature is necessary, but a uniformly heated chamber does not necessarily result in a uniformly heated product without proper consideration of the other factors[1] involved: (1) manner of heat application to the surface of the individual piece; (2) the rate of heating; (3) the time of exposure; and (4) the atmosphere of the furnace. Variation in product may result and difference in furnace design, in manner of placing the charge in the chamber, in the rate of heating, in the time of exposure, or in the rate of charging and discharging, which may result in difference in manner of heat application or heat transfer without any indication by the pyrometer of temperature variation within the chamber. Thus, the curve showing a variation of ± 10° from 1500° F., drawn by the automatic control pyrometer means little more than that the temperature at the end of the thermocouple is being controlled to within 10° of the desired temperature. It in no way indicates a uniform temperature of 1500° F. throughout the chamber. It cannot for it only measures the temperature at one point, the end of the thermocouple. The factors mentioned may be causing a very considerably different temperature in other parts of the furnace chamber.

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* The Connecticut Light and Power Company, Hartford, Connecticut

[1] J. A. Doyle, "Control of Industrial Heating Processes," *Journal Industrial & Engineering Chemistry*, **14**, 1005 (Nov. 1922).

Uniformity of heating is relative and absolute uniformity is rarely obtained either in the furnace chamber or in the uniformly heated product. The closest approach to a uniformly heated product is possibly that of a continuous furnace in which each individual piece is heated in the same manner, to the same temperature, at the same rate, for the same length of time, and discharged in the same manner. A high degree of uniformity of chamber temperature is found in immersion heating and in air tempering with automatic mechanical circulation of the furnace atmosphere. The box or batch type furnace is the farthest from the ideal both in uniformity of chamber temperature and in the production of a uniformly heated product. Only well-designed box or batch furnaces meet the requirement of relative uniformity of chamber temperature.

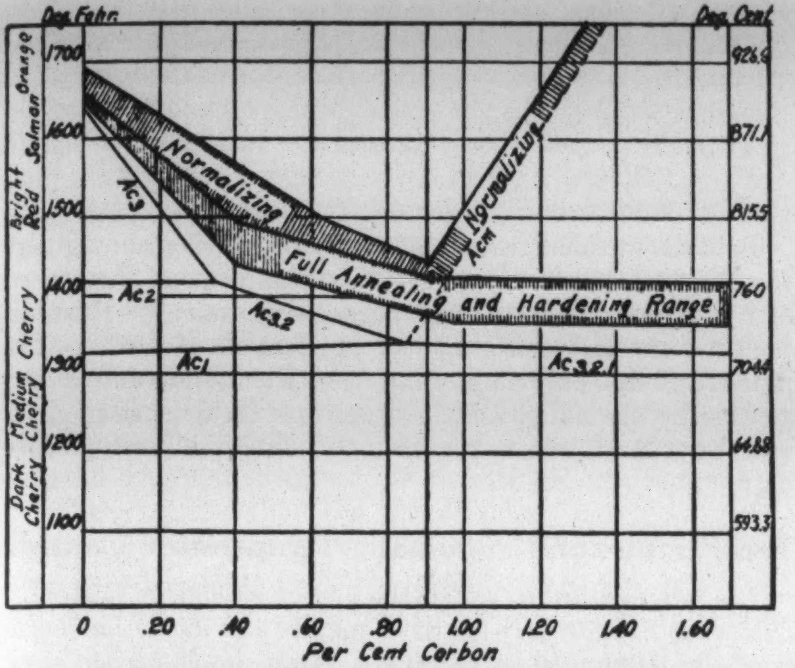


Fig. 1—Critical Range Diagram for Iron-Carbon Alloys

Because of the difficulty in securing absolute uniformity of heating it is fortunate that the transformation in structure of steel on heating above its upper critical range does not occur suddenly, but usually covers a range of 25 - 50° F., so that it is customary to adopt a temperature slightly above the actual critical range, Fig. 1, in which the shaded portions are the permissable ranges for normalizing, annealing and hardening carbon steel with varying carbon contents.

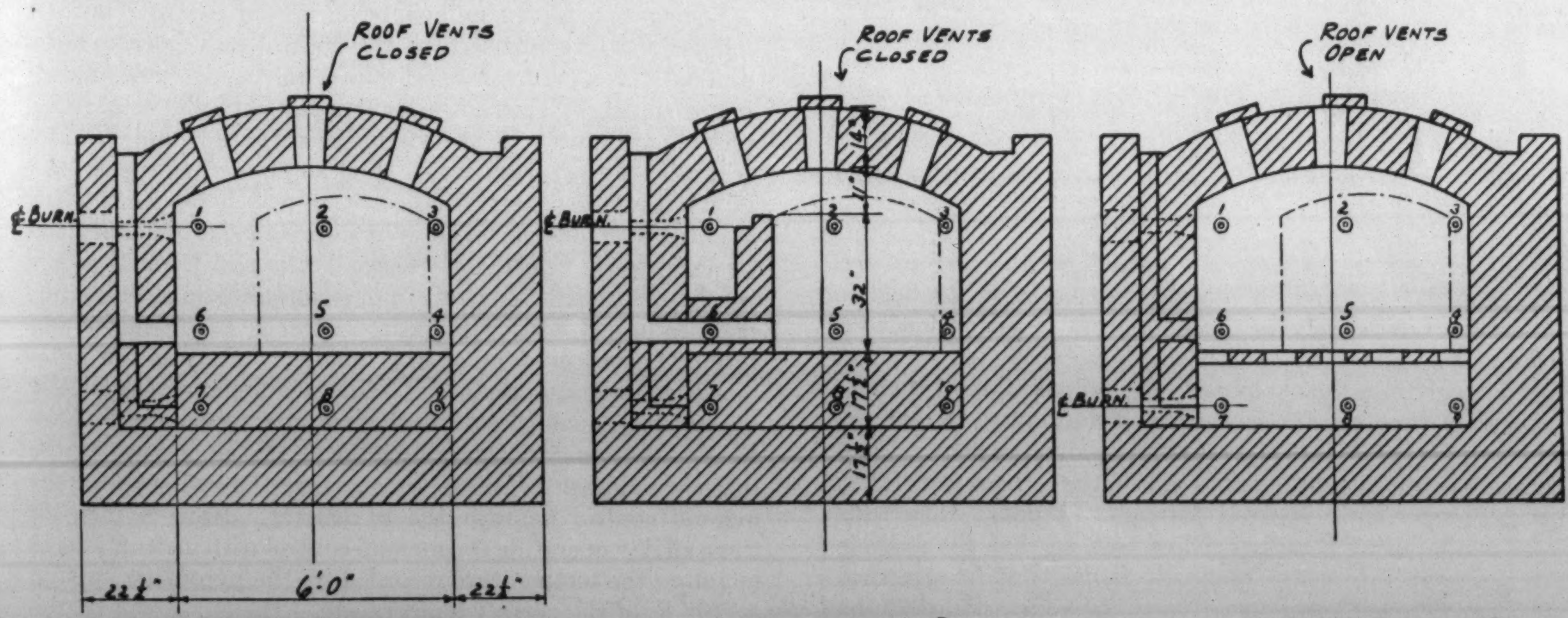
These ranges give some indication of the uniformity of heating necessary. A 0.2% carbon steel has a variation in the hardening and annealing range of only about 30° F., but the 0.6% carbon steel has 50° F., and the 1.0% carbon steel about 60° F., which suggests need of especial care in uniformity of heating of steels with a carbon content of 0.2% or less. The temperature width of the range as shown on the diagram does not mean, however, that there is not an exact temperature for a specific steel at which the best results could be obtained, but it will vary with the mass and shape of the piece. In practice it would also probably be found that if two pieces of steel of the same carbon content, the same weight and the same shape were heated, one in a furnace made by one furnace manufacturer and the other in a furnace built by another manufacturer, to exactly the same temperature as measured on the pieces themselves, the control pyrometer of the two furnaces would register two different temperatures, and neither the exact temperature of the piece. The temperature shown by the control pyrometer, would, however, indicate the correct temperature for heat treating a piece of steel of the same carbon content, of the same shape, the same size, when placed in the same position as the test piece in that furnace, but only in that furnace.

The degree of uniformity of heating which possibly may be expected in box type combustion furnaces with different methods[2] of firing is shown in Tables I and II.

Table I—Temperatures ° F. at Different Points—Box Furnace

Method of Firing	Test No.	Thermocouple Numbered in Fig. 2 1	2	3	4	5	6	Maximum Difference
Direct	13	1025	1100	1135	830	825	815	320
Direct	4	1735	1780	1765	1690	1715	1645	135
Direct	5	1765	1800	1800	1730	1745	1695	105
Side	12		1155	1140	910	875		280
Side	14		1610	1640	1600	1595		45
Side	10		1640	1650	1610	1595		55
Side	11		1710	1705	1655	1640		70
Under	8	970	980	1025	970	970	960	65
Under	7	1565	1590	1620	1615	1575	1585	55
Under	9	1660	1670	1700	1710	1670	1660	50

The test furnaces had inside dimensions of width 72″, depth 60″ and length 48″, one being direct fired, one side fired and the third underfired as shown in Fig. 2. The furnaces were soaked at various temperatures for eight hours, and readings of thermocouples located in the heating chamber, Fig. 2, were taken at regular time intervals. The thermocouples were inserted some distance into the furnace through the rear wall, so that their points were all in the same cross-sectional plane. The furnaces were fired by three natural gas burners.



DIRECT FIRED - A

SIDE FIRED - B

UNDER FIRED - C

Fig. 2—Arrangement of Test Furnaces for Determination of Temperature Distribution

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[2] M. H. Mawhinney, "Temperature Distribution in Combustion Furnaces." Presented at Cleveland meeting, American Society of Mechanical Engineers, Sept. 11, 1929.

Table II—Effect of Method of Firing on Horizontal and Vertical Variations of Temperature in Cross-Sectional Plane

Method of Firing	Test No.	Horizontal Variation 0° F.	Vertical Variation ° F.	Average Soaking Temperature ° F.
Direct	13	62	263	955
Direct	4	38	77	1722
Direct	5	35	65	1756
Side	12	10	256	1020
Side	14	18	26	1611
Side	10	13	42	1624
Side	11	5	61	1678
Under	8	32	25	979
Under	7	53	7	1588
Under	9	45	5	1678

The results show clearly that the highest degree of uniformity of heating is obtained with the underfired furnace, with the side fired next and the direct fired the poorest. At an average temperature of 1588° F. in the underfired furnace, the maximum temperature difference in the furnace chamber was 55° F. These experiments show the comparative uniformity of heating in a vertical cross-section from side to side of a combustion furnace fired in three different ways.

In the box type furnace a large part of the heat loss by radiation is through the door, and unless the flow of heat energy is greater at the front end than at the rear, or unless the furnace has a deep vestibule so that the charge is a considerable distance from the door, uniformity of heating will not prevail. Table III shows the temperature distribution at the rear and front end of an electric carburizing furnace, 42″ wide, 72″ deep with a 9″ rear vestibule at the front end, and 16″ high. Heating elements were located in the floor, sides and roof of the furnace. The rear temperature was taken by the thermocouple of the control pyrometer which projected 6″ into the furnace at the center about 6″ below the roof. The temperature at the front was taken by a thermocouple which projected 22″ beyond the inside of the door, at approximately the same height as the rear thermocouple and in the center of the door. The end of the thermocouple, thus extended 13″ into the heating chamber proper. This rough field test showed a difference in temperature of 60° F. between the front end and rear end. The uniformity was improved by inserting heating elements in the door. The situation might have been handled by insertion of higher capacity heating elements in the front of the side walls, floor or roof.

Table III—Temperature ° F. at Rear and Front of Box Furnace

Time	Temperature 6 in. from Rear Wall of Chamber ° F.	Temperature 22 in. from Inside Wall of Door ° F.	Variation in Temperature ° F.	Remarks
9:28 A.M.	1510	..	...	Loading pots
9:35	1000	..	...	Door closed
10	1200	1010	190	
10:25	1320	1200	120	
10:40	1400	1280	120	
11:2	1500	1405	95	
11:5	1510	1415	95	
11:25	1510	1460	50	
12:10	1510	1450	60	
12:50	1510	1450	60	Unloading

The temperature difference in a small electric box furnace, 36″ deep, 12″ wide and 8″ high was explored in the field to determine how closely to the door work could be loaded—Table IV. The furnace contained an alloy retort which fitted snugly into the chamber. The temperature at the rear was taken from the thermocouple of the control pyrometer, which projected 3″ into the retort, 5″ above the floor. Temperature readings at different depths in the furnace were taken by a thermocouple inserted through the door. The tests were made during a radiation loss test, so that the average furnace temperature was gradually falling, but for practical purposes were sufficient to arrive at the conclusion that the furnace should not be loaded up to within 10″ of the door when heating for hardening at 1540° F.

Table IV—Temperature ° F. from Front to Rear of Box Furnace

Time	Power	Temperature 3″ from Rear Wall of Chamber ° F.	Distance of End of Exploring Thermocouple from Inside of Door	Temperature Indicated by Exploring Thermocouple ° F.	Variation in Temperature ° F.
12:45 P.M.	Off	1580	6 in.	1500	80
12:50	Off	1580	6 in.	1500	80
12:55	Off	1560	8 in.	1510	50
1	Off	1545	10 in.	1510	35
1:05	Off	1535	12 in.	1505	30
1:07	On	1530	14 in.	1505	25
1:10	Off	1530	16 in.	1510	20
1:15	Off	1540	16 in.	1520	20
1:20	Off	1530	19 in.	1515	15
1:22	On	1525	19 in.	1505	15

It is thus evident that uniformity of heating throughout the chamber of a furnace is relative regardless of the source of heat, and that to a large degree uniformity of chamber temperature and uniformity of application of heat to the product is not only important from the standpoint of the grain structure and physical properties of the finished product but also with respect to prevention of distortion during heating.[3]

Temperature and Automatic Temperature Control

The temperature to which the charge should be heated is somewhat definite and for most metals and alloys has been carefully determined by research. For a simple carbon steel it is determined from the critical range diagram, Fig. 1. The furnace engineer provides a furnace with a suitable atmosphere and a relatively uniformly heated chamber in which the charge is distributed under the supervision of practical metallurgical supervision in the manner most apt to result in uniform application of heat to the product. The research metallurgist specifies the temperature to which the product is to be uniformly heated and assists the practical metallurgist in determining the proper rate of heating of the product and period of holding it at the correct temperature. What is the function of automatic temperature control?

Modern automatic temperature control of the simple arrangement which would be in effect with all burners or heating elements on a single control pyrometer performs three functions: (1) it controls the quantity of heat liberated in the furnace chamber to the extent that approximately the correct temperature is maintained at the end of the control thermocouple; (2) by limiting the temperature at this point to approximately the correct temperature, it maintains the relative uniformity already established by the efficiency of furnace design; and (3) it saves labor and possibly permits the employment of less skilled labor in large installations. There are a number of modifications of this simple control. A furnace may have a number of burners or groups of burners independently controlled, or the control may operate automatically on a predetermined time-temperature cycle of heating or cooling. Through its maintenance of the established relative uniformity of heating in the furnace chamber, automatic control prevents overheating and underheating at least at its point of control, and for this reason has been often credited with lowering of costs by improvement of quality and by decrease in rejections. Labor is the real item of saving by use of automatic control. For example, assume that a furnace equipped with automatic control is producing a uniformly heated product of high quality. Discard the automatic control and replace it with a manual or electrically operated manual control and recording pyrometer. Place the thermocouple of the pyrometer at the same point in the furnace chamber as before. Centralize the operation of the manual control beneath the pyrometer. Have a man sit there all day operating the manual control with instructions to maintain the temperature recorded by the pyrometer, within ± 10° F. of the correct temperature. His curve will be the

[3] J. F. Keller, "Why Metal Warps and Cracks," *Transactions American Society Steel Treating*, **9**, 373 (Mar. 1926).

same as that made by the automatic temperature control equipment, if his job depends on it.

The development of automatic temperature control for gas, electric and oil heated furnaces resulted in a more thorough understanding of the necessity of a uniformly heated product, which was not previously completely realized. With a more complete understanding, accurate manual control would have been employed more extensively before the development of automatic control, and the marked improvement in quality credited to automatic control would not have existed. Indirectly automatic control lowers the cost of furnace maintenance by preventing overheating of refractories and burning out of electric heating elements, but its big job is labor saving.

The fact that automatic temperature control simply maintains the relative uniformity of heating of the furnace chamber, already established by efficiency of furnace design, but does not create uniformity of chamber temperature, is shown by consideration of Fig. 2 and Table I. Equip the underfired furnace C with automatic control, set to control within ± 10° F., and using thermocouple No. 2 as its control point, set the control pyrometer at 1590° F. If the temperature as indicated by No. 2 thermocouple rises 10° F., the automatic control has reduced the input of heat energy into the furnace chamber to the lowest practical minimum, but in the meantime the temperature indicated from thermocouple Nos. 1, 3, 4, 5 and 6 will have all increased by 10° F., and as in the case of Test No. 7, there will still be a maximum temperature difference of 55° F. in the furnace chamber. The automatic temperature control has not improved the uniformity of heating; it has simply maintained it relatively as before. Thus, it will be evident that automatic temperature control is only one of a number of factors influencing the production of a uniformly heated product.

Rate of Heating

Too rapid a rate of heating results in localized heating. Non-uniformity of chamber temperature and improper loading also result in localized heating. Localized heating may cause deformation of the metal, and a change in its shape. Absolute elimination of localized heating is accomplished only when heat is absorbed by all surfaces at the same speed, and when the temperature of the outside and center of the piece are at all times the same. A very slow rate of heating is essential, so slow that it is not always commercially practicable. When deformation is encountered slow heating is helpful. Of course large steel pieces should be heated more slowly than small ones and often should not be placed cold in a hot furnace, but in a furnace which is at a temperature of less than 700° F.

The effect of localized heating[3] is shown in Fig. 3. A square die block has been placed in a cold furnace and the burners lighted. Consider the upper half of the block to be (A) and the lower half (B). The top half (A) heats first, expands and extends in length, causing this portion to hump upwards in the center. This hump continues to increase until the portion (A) is about 650° F. As the temperature rises beyond 650° F., Fig. 4, the metal (A) becomes weaker. At this point in the heating, the resistance of the cold portion (B) would cause a slight deformation (upsetting) in the weaker portion (A). As the lower portion (B) increases in temperature there is a slight reversal in the hump. Both ends rise with further compressive action on the top and weaker portion (A). This action continues until the stresses are equalized, and the bar would be warped if removed from the furnace at that time.

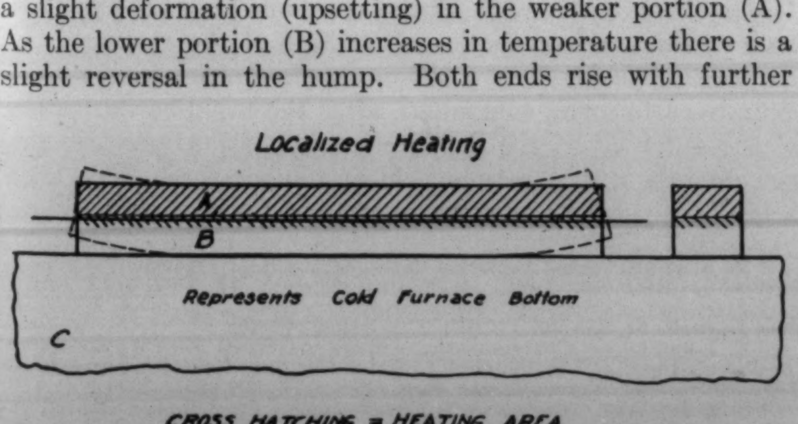

Fig. 3—Deformation from too Rapid and Localized Heating

Consideration of the following fundamental points indicate the cause of deformation resulting from localized heating.

(1) On heating, steel retains its strength at atmospheric temperature until it has been heated to about 650° F., Fig. 4, above which its strength decreases rapidly reaching a minimum at its upper critical range.

(2) On heating, steel expands in all directions in proportion to the increase in temperature, provided that no resistance is offered to its normal expansion.

(3) If resistance is offered to its normal expansion on heating, the expansion follows the course of least resistance and deformation takes place due to the interposed resistance and loss of strength of the steel above 650° F.

If the die block in Fig. 3, had been placed on its edge and heated slowly without localized heating to about 650° F., portion (B) would have entered the temperature range above which the strength decreases rapidly, at the same time as (A) so that it would have set up no resistance to expansion of (A); both would expand uniformly together and little or no deformation would have resulted.

The determination of the rate of heating is largely a matter of the experience and judgment of the metallurgist. It has been customary for many years to allow a heating time of one hour per inch of diameter or thickness, but variations from this standard are now found in the "Recommended Practice" of the American Society for Steel Treating. In all of the Recommended Practices, it is of interest to note that each Recommended Practice recognizes the importance of the position of the steel in the furnace and recommends "Place steel in furnace so as to expose the maximum surface area." The possibility of deformation in heating die blocks is indicated by the recommendation—"The temperature of the furnace used for this heat treatment should not be over 700° F. at the time the die blocks are charged into it." The recommended time for heating up carbon steel die blocks is 1 hr./in. of thickness, with the smallest dimension of the block taken as the thickness. But in annealing drop hammer die blocks of chromium-nickel steel, it is 1 hr./in. of thickness plus 1 hr., and in hardening 1 hr./in. of thickness, for steel containing carbon 0.5–0.7%, manganese, 0.4–0.8%, chromium 0.6–1.3 % and nickel 1.0 to 2.0%. A chromium-molybdenum hot forming die block made of steel containing carbon 0.6–0.7%, manganese, 0.5–0.8%, chromium 0.75–1.0% and molybdenum 0.6–0.9%, has a time of heating for annealing and spheroidizing of $1^1/_4$ hr./in. of thickness plus 1 hr., and for hardening $1^1/_4$ hr./in. of thickness. Other considerations than the possibility of deformation in determining the rate of heating are the chemical analysis of the steel and the structure desired in the finished product.

Time of Holding at Temperature

In practice the charge may be held at the correct temperature for varying periods for the following reasons:

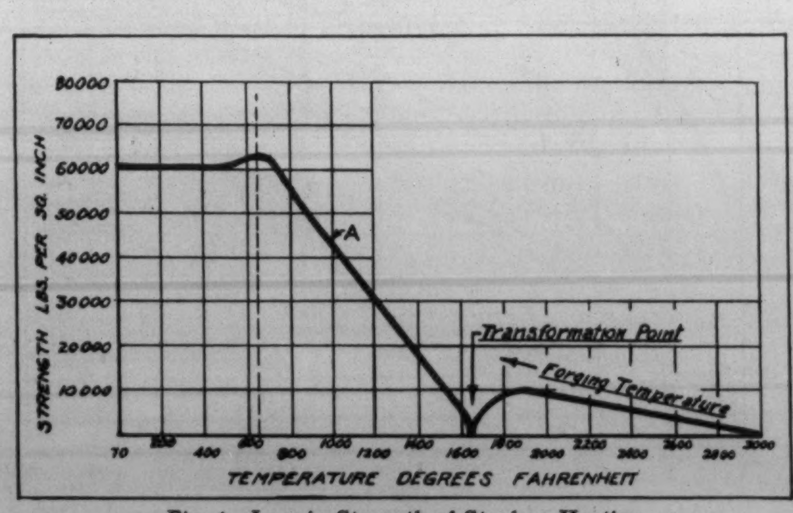

Fig. 4—Loss in Strength of Steel on Heating

(1) The rate of heat liberation in the furnace chamber has probably been more rapid than the capacity of the charge to absorb heat, so that the temperature of the furnace chamber has built up much more rapidly to the correct temperature than the temperature of the charge, and while the outside of the charge is at the correct temperature the inside is not. To bring the whole of the charge to the correct temperature it must remain in the furnace until saturation is completed.

(2) The charge must be held at the correct temperature until the desired new grain structure has formed and all internal stresses are relieved.

The necessity of holding the work at temperature to complete saturation divulges the fact that a uniform rate of heating has not been used, in that the rate of heating has not been slow enough to permit all parts of the charge to be at the same temperature at the same time. Localized heating has of necessity occurred, so that an absolutely uniformly heated product cannot result when all of the factors involved in the production of the absolutely uniformly heated product are considered. It is a procedure commonly followed in batch annealing and carburizing, and must be considered as a necessary compromise between theory and practice, in the present stage of development of industrial heating. In some plants it is carried to extreme by raising the temperature of furnace chamber during heating up to far above the correct temperature in order to produce a higher temperature gradient between the chamber and the work, thus promoting more rapid heating. In such cases the outside of the work is much overheated with an enlargement of grain size resulting.

Fig. 5 demonstrates several points which have been mentioned: (1) that the chamber temperature and the temperature of the work may be far different; (2) that indication of the correct temperature on the outside of the work is no indication of a current temperature at its center; and (3) the necessity of a long soaking period when heating large pieces of steel. The experiment[4] consisted in heating a 30-ton ingot to forging temperature in a coal-fired furnace with thermocouples located as follows: (1) in the furnace atmosphere, (2) on the surface of the ingot, (3) 12″ inside, (4) 36″ inside and (5) at the center of the ingot. After 10 hrs. of heating the outside of the ingot reached approximately its maximum temperature at 1240° C. (2265° F.) with the center of the ingot at 800° C. (1470° F.) a difference of 440° C. (795° F.). At this time the temperature of the furnace chamber was 1400° C. (2550° F.) or 160° C. (285° F.) higher than the outside of the ingot, a condition approximately maintained until the end of the heat. Eight hours of soaking was necessary to bring the center of the ingot to approximately the temperature of the outside. The average thickness of the ingot was 47″ and the total heating period 18 hr. or 0.38 hr./in. of thickness.

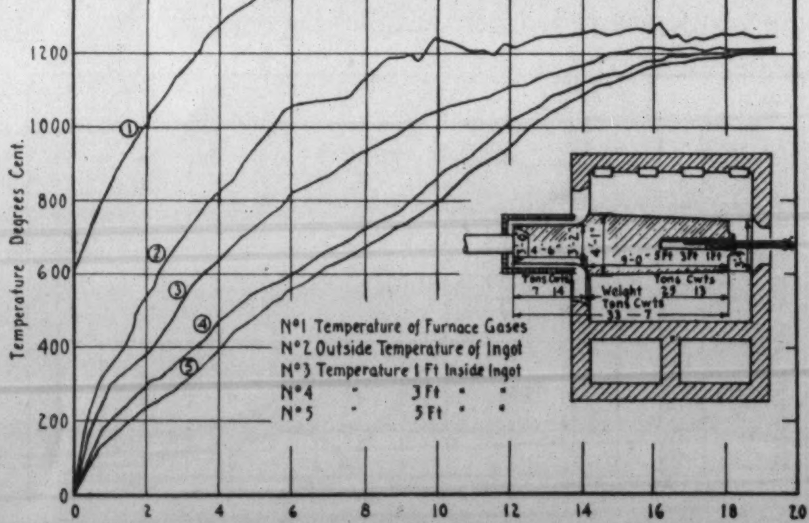

Fig. 5—Rate of Heating of 30 Ton Ingot at Various Points

The time required to heat a steel body under constant heat potential has been investigated by Leeds,[5] Law,[6] and Janitzky.[7,8] Leeds heated pieces of steel approximately 0.5% carbon, ranging in size from 2 to 12″ diam. by 24″ long in a furnace at a constant heat potential of 1000°, 1200°, 1400°, 1500° and 1600° F. Law heated an 18″ steel cube to 1650° F. Janitzky[7,8] through experimentation to determine time constants and mathematical calculation has developed an empirical formula by which the time required to heat different sizes and shapes to a given head temperature can be calculated.

Table V shows that the method of Janitzky is sufficiently accurate for practical purposes. It is also evident that the customary heating time of 1 hr./in. of thickness is not only ample in most cases, but is more than ample in cases where it is not objectionable from the standpoint of deformation or grain structure to bring the furnace quickly to a constant heat potential. The data, of course, applies only to one solid piece of steel in each case, and can only be used as a general guide. The higher the temperature the shorter was the time required to reach temperature due undoubtedly to the greater difference in temperature between the furnace chamber and the work. The data at 1400° F. is probably out of line with that taken at other temperatures, because the steel used in Leeds' experiments contained 0.5% carbon, the critical point of which is 1400° F. It will be noted that while the cylindrical pieces of small diameter reached temperature more quickly than the large ones, the rate of heating was slower.

Table V—Time Required to Heat Steel Under Constant Heat Potential

Temperature to which Work Was Heated ° F.	Shape	Calculated Length of Time-Hours (Janitzky)	Observed Length of Time Hrs.	Hrs./In. of Thickness or Diam.
1650	18″ cube	4.75	4.5 (Law)	0.25
1600	12″ round	4.97	4.7 (Leeds)	0.39
1600	8″ round		3.0 (Leeds)	0.37
1600	4″ round		1.7 (Leeds)	0.42
1600	2″ round		1.0 (Leeds)	0.50
1500	8″ round	3.7	4.0 (Leeds)	0.50
1400	12″ round		8.1 (Leeds)	0.68
1400	8″ round	4.5	4.8 (Leeds)	0.60
1400	4″ round		3.2 (Leeds)	0.80
1400	2″ round		2.6 (Leeds)	1.30
1200	12″ round		5.6 (Leeds)	0.46
1200	8″ round	3.53	3.5 (Leeds)	0.43
1200	4″ round		2.5 (Leeds)	0.62
1200	2″ round		2.1 (Leeds)	1.05
1000	12″ round		6.1 (Leeds)	0.50
1000	8″ round	4.17	4.2 (Leeds)	0.52
1000	4″ round		2.8 (Leeds)	0.70
1000	2″ round		2.4 (Leeds)	1.20

Time of holding at temperature is of special importance in developing grain structure in a number of operations, among them; annealing of steel which has been subjected to severe mechanical working; annealing of severely overheated steel; annealing of steel castings; carburizing of steel; and annealing of gray iron. The time at temperature in annealing of steel which have been severely worked or overheated, must be worked out by experimentation on the job. For the annealing of carbon steel castings, the Recommended Practice of the American Society for Steel Treating is to heat slowly to temperature, and hold at temperature one hour for each one inch of thickness of the largest section of the castings. In carburizing of steel at a definite temperature and with a definite carburizing compound, after the rapid carburization of the outer layer, the depth of carburization increases approximately with the time held at temperature. The time held at temperature must be determined for each application, because of the varying factors, such as the type of furnace and its loading and carburizing compound used. In annealing of gray iron to increase machinability by precipitation of combined carbon as graphite, it is desirable to bring the temperature of the casting up with the furnace to 1400° F. and hold for from one half to three hours.[9] In the annealing and hardening of steel the time at temperature varies with the operation, material, shape and mass of the work as indicated by the Recommended Practices of the American Society for Steel Treating some of which are the following: one fifth of total heating time, normalizing and hardening of carbon steel die blocks, hardening of alloy steel die blocks; 1 hr./in. of thickness or diameter, annealing and spheroidizing carbon steel die blocks and alloy steel drop hammer die blocks, 0.6 to 1.3% chromium and 1.0–2.0% nickel, annealing and spheroidizing of other alloy steel die blocks, $1^{1}/_{4}$ hr./in. of thickness or diameter; $^{1}/_{2}$ hr., annealing after forging and before machining of taps and milling cutters after machining $^{1}/_{4}$ hr. For the annealing of die blocks the recommended time of temperature is approximately the same as time of heating to temperature.

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[4] W. H. Hatfield, "The Application of Science to the Steel Industry," *Transactions American Society for Steel Treating*, **15**, 817 (May 1929).

[5] M. E. Leeds, "Some Neglected Phenomena in Heat Treatment of Steel," *Proceedings American Society for Testing Materials*, **15**, Pt 2, 5–22 (1915).

[6] E. F. Law, "Effect of Mass on Heat Treatment," *Journal Iron and Steel Institute*, **97**, 333–347 (1918); Discussion 348–352.

[7] E. J. Janitzky, "Characteristics of Heating Curves, Their Applicability for Calculating the Time Required to Reach Constant Heat Temperatures," *Transactions American Society for Steel Treating*, **5**, 201 (Feb. 1924).

[8] E. J. Janitzky, "Temperature Distribution in Steel Bodies Heated at a Constant Heat Potential," *Transactions American Society for Steel Treating*, **6**, 619 (Nov. 1924).

It is apparent that uniformity of heating application, temperature control, control of rate of heating and the correct time at temperature are all about equally important component factors in the production of the uniformly heated product.

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[9] E. L. Roth, "Effect of Heat Treatment on the Combined Carbon in Gray Cast Iron," *Transactions American Society for Steel Treating*, **12**, 27 (July 1927).

Tension and Torsion Tests

By R. Worthington*

A series of tensile and torsion tests made at the laboratory of the International Nickel Co., Inc. on three non-ferrous alloys have given rather significant results. Although the properties of different metals are common knowledge, these test data give a better opportunity than usual to compare both relationship between the different property values of a single metal and the variation in this relationship with different metals.

The alloys—high-strength copper-zinc alloy carrying 6% aluminum and low contents of iron and manganese; silicon-manganese bronze; and a nickel-copper alloy—were obtained from the market in the form of rod suitable for pump rod and propeller shafting. All three types of alloy are in more or less wide use because of combined corrosion resistance and strength. In common practice, rod of the copper-zinc alloy is produced by hot-rolling; rod of the silicon-manganese bronze by cold-drawing hot-rolled metal to approximately a 20% reduction in diam., and rod of the nickel-copper alloy by cold-drawing the hot-rolled metal in two passes with an intermediate anneal to a total reduction of about 20%, followed by a low-temperature stress-relief anneal. The tensile values obtained in the tests under discussion are consistent with those of rod of these histories.[1]

	Complex Copper-Zinc Alloy	Silicon-Manganese Bronze	Nickel-Copper Alloy
	Tensile Tests		
Ultimate strength, lbs./sq. in.	113,500	108,750	95,000
Yield point, lbs./sq. in.	67,000	69,750	79,000
Proportional limit, lbs./sq. in.	49,250	36,000	47,500
Elongation in 2″, %	12.5	8	25
Reduction in area, %	16.3	29.9	58.6
Modulus, lbs./sq. in.	12,500,000	15,000,000	28,750,000
	Hardness Tests		
Rockwell B	102	99	98
Rockwell C	20	18	15
Brinell (3000 kg.)	266	248	228
	Torsion Tests		
Ultimate strength, lbs./sq. in.	91,600	94,200	81,300
Yield point, lbs./sq. in.	43,400	81,300	63,500
Proportional limit, lbs./sq. in.	39,200	47,300	50,300
Total twist to fracture, degrees	290	230	4,920
Angle of twist degrees per in.	20	16	320
Fracture	Irregular[2]	Square	Square
Modulus, lbs./sq. in	13,075,000	5,750,000	8,575,000

[2] Deep seams and piping.

Rod for the tensile test was machined to 0.505-in. diam., 2-in. gage length. In the torsion tests the copper-zinc alloy specimen was machined to $^{3}/_{4}$-in. diam. to permit shaping the grip section in order to prevent slippage. The other alloys were twisted full-size (1-in. diam.). The yield point in tension was taken at an elongation of 0.01 in. in 2 ins., the yield point in torsion as the stress at which the linear shear of the outermost fiber was 0.01 in. per in. of gage length.

The first point it is desired to call attention to is the relation between ultimate strength and proportional limit. The silicon-manganese bronze has a definitely higher ultimate strength in tension than the nickel-copper alloy, but on the other hand a just as definitely lower proportional limit and yield point. This is a case—and there are many similar cases—where the ultimate tensile strength is an incorrect index of the elastic strength. There are many applications—springs, marine propeller shafting, etc.—where elastic limit is a much more significant property than the ultimate tensile strength, and somewhat more significant than the yield point. Professor Moore (*Mechanical Engineering*, **15**, 739 (1929)), believes that "The significance of elastic limit and proportional limit as indices of elastic strength are greatly over-estimated," yet it would seem to be going a little too far to concur in his suggestion that the values of elastic limit and proportional limit be disregarded by designing engineers.

It is true that the yield point, in view of the facts that this is more easily determined and that some elastic deformation in many cases is permissible, is better or acceptable for many purposes. The main difficulty in using yield point lies in the fact that values of yield point determined according to different definitions vary somewhat, and the principal merit in basing calculations on the true elastic strength is that we narrow down by just that much the field of unknown variables.

Comparisons between metals on the basis of ultimate tensile strength are more likely than not to be misleading.

The second point to be mentioned has to do with the relation between strength and ductility. As non-ferrous metals are hardened by cold-work, the curve for proportional limit (and yield point) approaches that of ultimate strength. Since ductility decreases, of course, with cold work, the difference between the values for proportional limit and ultimate strength is a rough measure of ductility. The figures given above point out definitely that different metals cannot be compared in this manner, even though specimens of the same metal with different cold-work treatments may be. Thus, the nickel-copper alloy has the least gap between ultimate strength and proportional limit yet also decidedly higher elongation.

In the torsion tests these same points are illustrated, particularly in the comparisons between the silicon-manganese bronze and the nickel-copper alloy. The nickel-copper alloy has a decidedly lower ultimate strength and yield point and yet somewhat higher proportional limit; and the gap between ultimate strength and proportional limit is considerably less in the nickel-copper, yet this has a much greater torsional ductility than the silicon-manganese bronze, as indicated by the twist.

The tensile test gave no indication that the nickel-copper alloy would have such remarkable ductility in twisting. Its plastic twist was even more surprising in view of the fact that the alloy was already in a considerably work-hardened condition from cold-drawing. Good ductility, as Professor Moore has pointed out, is significant not as a value for design formulae but as "an insurance factor against injury by occasional overstress."

No explanation is offered for the curious, out-of-line torsional modulus obtained for the complex copper-zinc alloy.

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* Development and Research Dept., International Nickel Company.

[1] The proportional limit in tension, the elongation, and the reduction in area of the specimen of silicon-manganese bronze tested are somewhat below values obtained by the manufacturer of this alloy on $^{1}/_{2}$-inch rod.

Hardness Determinations on Magnesium Alloys

By L. B. Grant† and A. W. Winston‡

Hardness determinations are frequently made on metals to indicate changes in other related properties. In studying the effects of alloy composition, mechanical working and heat treatment, hardness tests offer a convenient and inexpensive method for following the changes that take place.

In view of the increasing interest in magnesium and its alloys, it was thought advisable to secure hardness data on them and to arrange these results in convenient and usable tables and curves. The hardness tests compared were Brinell, Scleroscope and Rockwell "E."

Of these three methods, the Brinell is perhaps the most widely used in scientific work. It is, however, rather slow and inconvenient in operation, involving as it does the measurement of the indentation diameter with a microscope and the translation of this into the Brinell hardness number by the use of tables or calculations. Another disadvantage of the Brinell hardness test is the fact that on the softer cast magnesium-base alloys, having fairly large grains, the indentation is very irregular in shape and is, therefore, hard to measure correctly.

The Scleroscope is quick and easy to operate, particularly the self-recording type. Despite this fact, it has not found extensive use in work on magnesium alloys, largely because of the necessity for very careful preparation of the sample in order to secure check results.

The Rockwell hardness test has proved to be rapid and convenient in operation and checks well between various readings on the same specimen. It has an advantage over the Brinell in that a smaller impression is made, thus permitting the use of smaller specimens. Somewhat more care is necessary in the preparation of the surface which should be polished down to No. 0 emery paper. The bottom of the specimen should be rough polished and must be approximately parallel to the top surface.

The curves in Figs. 1 and 2 are the result of many hardness tests on several types of magnesium-base alloys containing up to 16% added metals and after a variety of treatments, such as casting, heat treating, age-hardening, forging, extruding, etc. The data in Table I have been taken from the curves in order to put the information into a more convenient form for use.

Brinell tests were made using a 10 mm. ball with a 500 kg. load applied for 30 seconds. Scleroscope tests were run on a Shore self-recording machine with a universal hammer. Rockwell tests were made on a Model $2^1/_2$ H machine. The "E" scale was found to be the most satisfactory for use on all magnesium alloys. This consists of the $^1/_8$" diam. ball penetrator and the 100 kg. major load, with the final hardness readings being taken on the red numerals of the dial. Specifications for the Rockwell "E" test have been published by the manufacturers of the Rockwell Hardness Tester.

The data obtained from these tests show that alloy composition, heat treatment and mechanical working of magnesium-base alloys do not appreciably affect the relationship between Brinell, Scleroscope and Rockwell "E" hardness readings. It is interesting to note that on all magnesium alloys the Scleroscope hardness is approximately one-half of the Brinell hardness. While the Rockwell "E" readings are simply arbitrary scale divisions, it has been shown that they can be translated directly into Brinell hardness numbers by the use of the conversion curves and tables given above.

Table I—Rockwell-Brinell-Scleroscope Relationships for Magnesium Alloys

Rockwell E	Brinell	Scleroscope	Rockwell E	Brinell	Scleroscope
−20	29.6	15	41	42.2	22
−19	29.7	15	42	42.5	22
−18	29.8	15	43	42.8	22
−17	29.9	15	44	43.1	22
−16	30.0	15	45	43.5	22
−15	30.2	15	46	44.0	23
−14	30.4	15	47	44.3	23
−13	30.7	16	48	44.8	23
−12	30.8	16	49	45.2	23
−11	30.9	16	50	45.6	24
−10	31.0	16	51	46.0	24
− 9	31.2	16	52	46.4	24
− 8	31.5	16	53	46.9	24
− 7	31.8	16	54	47.3	24
− 6	31.9	16	55	47.9	25
− 5	32.0	16	56	48.4	25
− 4	32.1	16	57	48.9	25
− 3	32.3	16	58	49.4	25
− 2	32.4	17	59	49.9	26
− 1	32.6	17	60	50.5	26
0	32.8	17	61	51.0	26
1	33.0	17	62	51.8	27
2	33.1	17	63	52.4	27
3	33.3	17	64	53.1	27
4	33.6	17	65	53.9	28
5	33.8	17	66	54.6	28
6	34.0	17	67	55.6	28
7	34.1	18	68	56.5	29
8	34.3	18	69	57.4	29
9	34.5	18	70	58.2	30
10	34.8	18	71	59.2	30
11	35.0	18	72	60.2	31
12	35.2	18	73	61.3	31
13	35.4	18	74	62.3	32
14	35.7	18	75	63.4	32
15	35.9	18	76	64.5	33
16	36.0	19	77	65.5	33
17	36.2	19	78	66.8	34
18	36.4	19	79	68.0	34
19	36.6	19	80	69.2	35
20	36.8	19	81	70.6	35
21	37.0	19	82	72.0	36
22	37.2	19	83	73.4	37
23	37.5	19	84	75.0	38
24	37.7	19	85	76.6	38
25	37.9	20	86	78.2	39
26	38.1	20	87	80.0	40
27	38.3	20	88	81.5	41
28	38.6	20	89	83.0	41
29	38.9	20	90	84.8	42
30	39.0	20	91	86.3	43
31	39.2	20	92	88.2	44
32	39.5	20	93	90.3	45
33	39.8	21	94	92.5	46
34	40.0	21	95	94.6	47
35	40.3	21	96	96.7	48
36	40.5	21	97	99.0	49
37	40.8	21	98	101.8	50
38	41.1	21	99	104.0	51
39	41.5	22	100	106.5	52
40	41.8	22			

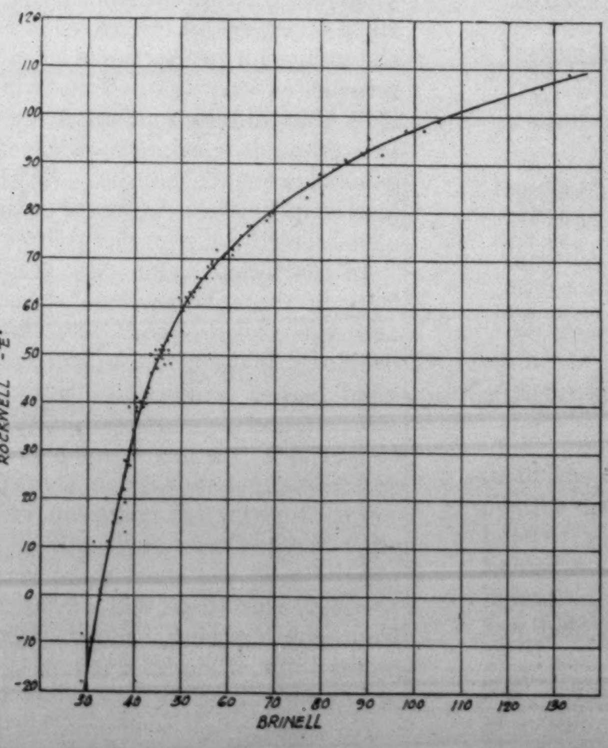

Fig. 1—Rockwell-Brinell Relationships on Magnesium Alloys

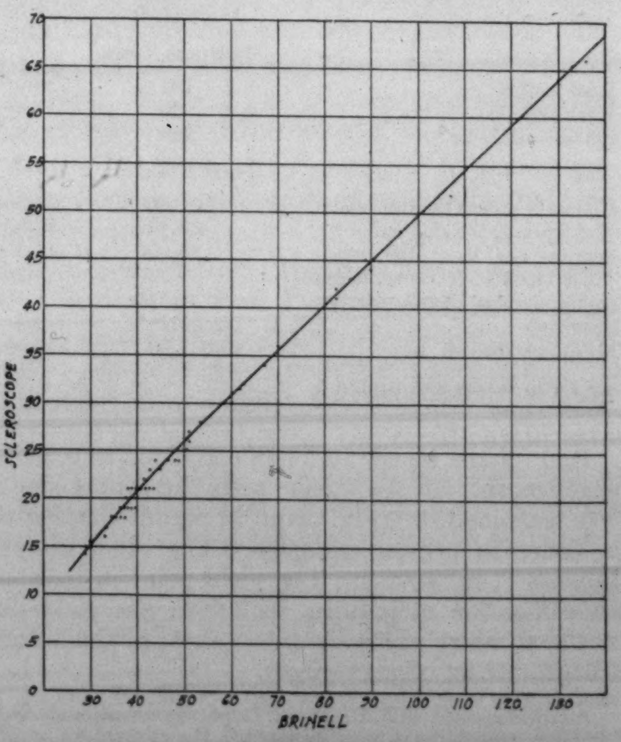

Fig. 2—Scleroscope-Brinell Relationships on Magnesium Alloys

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Correlated Abstract

Dr. Gillett, the editorial staff and specially selected contributors will prepare abstracts reviewing the work recently reported pertaining to certain subjects. These reviews will take into consideration the work of a number of workers. The current literature will be covered in the Abstracts of Current Metallurgical Literature.

Phases of the Metastable Iron-Carbon Constitution Diagram

By R. L. Dowdell[*]

Introduction

The previous writers of this series of correlated abstracts on the iron-carbon equilibria, namely Ellis, Epstein and Krynitsky, have discussed the researches of many investigators instrumental in the evolution of the presen iron-carbon diagram. A limited discussion only has been given relative to the critical ranges of steels and special features of the equilibria, so it is the aim of this abstract to correlate in a limited manner the hypo-eutectoid alloys of iron and carbon in the metastable system.

The Cementite Phase

The term, cementite, was coined by the late Dr. Henry Marion Howe to represent the hard and brittle white constituent which cemented most of the metastable iron-carbon alloys.

Cementite or Fe_3C, which theoretically contains 6.67% carbon, was X-rayed rather recently by Westgren and Phragmen[1]. The authors first found that its space lattice was practically unsolvable by the "powder" method so plates of spiegeleisen were measured with a goniometer. Cementites were isolated from pearlitic steels, cast iron, spiegeleisen and cohenite (carbide from meteorites) and all gave the same pattern. The unit crystal lattice was found to be that of an orthorhombic parallelopiped of large size (4 Fe_3C) having lattice dimensions of 4.518, 5.069 and 6.736 A. U. and a density of 7.68 ± 0.05. Their work established quite well that the compound is Fe_3C instead of Fe_2C, $Fe_{24}C$, etc., proposed by early investigators.

The A_0 transition—Honda and Takaoi discovered the A_0 change in Fe_3C by magnetic analysis. Later Honda and Murakami[2] stated that the A_0 took place at 215° C., and that it had the same nature as the A_2 of ferrite. Honda stated that the transformation was progressive and extended from the lowest temperature to 215° C. and that during heating and cooling the transformation began and terminated at the same temperature (215° C.). The transformation was observable in all alloys containing free cementite. In a later paper, Honda[3] stated that the A_0 and A_1 transformations increased in magnitude as the carbon content increased and confirmed the previous work.

The Alpha Phase

The alpha phase, usually termed ferrite, was also named by Dr. Howe to represent the fairly pure iron matrix of thoroughly annealed low carbon steels.

Hull,[4] Westgren and Phragmen,[1] Wever[5] and others found ferrite to be of body-centered cubic lattice with a unit parameter of 2.86 A. U.

For a considerable time it has been believed that this phase contained small amounts of carbon, silicon, manganese, etc., in a state of solid solution. In order to account for the coalescence of carbide particles in carbon steels when quenched steels are heated to temperatures below the A_1 transformation to form large carbide particles (granular pearlite), it is necessary that ferrite be a solvent for this diffusion reaction. It does not seem plausible, however, that the large lattice of Fe_3C will diffuse but it is more likely that carbon atoms of smaller size migrate through the ferrite by a sort of interchange as mentioned by Guertler.[6]

Differences of opinion exist between researchers on this question and on the amount of carbon actually dissolved in the ferrite phase at different temperatures. The iron-carbon constitution diagrams proposed by Sauveur, Roberts-Austen, Roozeboom, Carpenter and Keeling, Benedicks, Rosenhain, Upton, Ruff and Honda did not show a solubility field at the ferrite side of their diagrams. Within the last ten years, considerable attention has been given to the solubility of carbon in the alpha phase in the vicinity of the A_1 transformation temperature.

Scott[7] published a number of thermal (heating and cooling) curves which showed that A_1 could not be detected in an iron carbon alloy of 0.041% carbon. Islands of pearlite were not detected in a steel containing 0.030% carbon and less. He fixed the solubility of carbon in alpha at 0.035% at the temperature of A_1.

Berliner[8] showed a very distinct Ac_1 and Ar_1 on a fairly pure iron-carbon alloy of 0.07% carbon.

Pilling[9] found the solubility of carbon in ferrite at room temperature to be 0.005% by the use of a special nitro-benzol etchant. In the same year, Yensen[10] indicated the solubility of carbon in ferrite at room temperatures to be between 0.006 and 0.008%.

Sauveur and Krivobok[11] examined an electrolytic iron-carbon alloy containing 0.06% carbon and could not find Fe_3C in the alloy after slow cooling. They stated that 0.06% carbon could exist in a state of solid solution in the ferrite.

Guthrie[12] found cementite in Armco iron of 0.02% carbon and described a special streamer of Fe_3C which appeared to be forming pearlite in a ferrite grain.

Hatfield[13] stated that no pearlite was present in steel below 0.04% carbon and that none could be detected in steel of 0.05%. He suggested the possibility that carbon and oxygen might both be present as dissolved carbon and ferrous oxide.

Yameda[14] concluded that the solubility of carbon was at least less than 0.01% at room temperatures while Sisco[15] states that "a small amount of cementite equivalent to about 0.05% carbon is soluble in alpha ferrite."

Whitely[16] found a slight amount of undissolved Fe_3C after quenching a steel of 0.035% carbon, which had low amounts of impurities, from 720° C. He concluded that the maximum solubility of carbon in alpha at 720° C. was slightly less than 0.035% and probably 0.03%. He also claimed that on tempering, the quenched steels would precipitate Fe_3C which rapidly migrated to the ferrite grain boundaires.

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[*] Metallurgist, Bureau of Standards.

[1] A. Westgren and G. Phragmen, "X-ray Studies of the Crystal Structure of Steel," *Journal Iron & Steel Institute*, **105**, 241 (1922).

[2] K. Honda and T. Murakami, "On the Thermomagnetic Properties of the Carbides Found in Steels," *Science Report, Tohoku Imperial University*, **6**, 23 (1917).

[3] K. Honda, "On the A_0 Line in the Equilibrium Diagram of the Iron Carbide System," *Science Report, Tohoku Imperial University*, **15**, No. 2, 247–250 (1926).

[4] A. W. Hull, "The Powder Method of X-ray Analysis," *Physical Review*, **9**, 681 (1917).

[5] F. Wever, "On the Constitution of Technical Iron," *Zeitschrift für Electrochemie*, **30**, 376 (1924).

[6] W. M. Guertler, "The Corrosion of Metals—Memorial Lecture in honor of Dr. E. D. Campbell," *8th Annual Convention of American Society of Steel Treating*, Chicago, Sept. 1926.

[7] H. Scott, "What Is Steel?" *Chemical & Metallurgical Engineering*, **27**, 1156 (1922).

[8] J. F. T. Berliner, "Preparation and Properties of Pure Iron Alloys. Pt. IV. Determination of the Critical Ranges of Pure Iron Carbon Alloys by the Thermo-electric Method," *Scientific Papers, Bureau of Standards*, No. 484 (1924).

[9] N. P. Pilling, "Micrographic Detection of Carbides in Ferrous Alloys," *Transactions American Institute Mining & Metallurgical Engineers*, **70**, 254 (1924).

[10] T. D. Yensen, "Magnetic and Electrical Properties of the Ternary Alloys Fe-Si-C," *Journal American Institute Electrical Engineers*, **43**, 455–464 (1924).

[11] A Sauveur and V. N. Krivobok, "Dendritic Segregation in Iron Carbon Alloys," *Journal Iron & Steel Institute*, **112**, 313 (1925).

[12] R. G. Guthrie, "Sample Preparation for High Power Photomicrography," *Transactions American Society Steel Treating*, **7**, 337 (1925).

[13] W. H. Hatfield, "Discussion—Physical Chemistry of Steel Making Processes," *Transactions Faraday Society*, **21**, 272 (1925).

[14] Y. Yameda, "On the Solubility of Carbon in Pure Iron," *Science Report, Tohoku Imperial University*, **15**, 851–855 (1926).

[15] F. T. Sisco, "Constitution of Steel and Cast Iron," *Transactions American Society of Steel Treating*, **10**, 463 (1926).

[16] J. H. Whitely, "The Solution of Cementite in Alpha Iron and Its Precipitation," *Journal Iron & Steel Institute*, **116**, No. 2, 293 (1927).

In Hanson's[17] discussion of Whitely's paper, it was suggested that age-hardening experiments be tried with low carbon irons. He predicted that raising the temperature would first harden it and then soften it.

It is of interest to note that Masing and Koch[18] obtained age-hardening by both natural and artificial ageing and noted a marked increase in hardness.

Tamura[19] stated that the solubility of carbon in alpha at the A_1 temperature was 0.034% while at room temperatures he believed it to be zero and at 1486° C. (peritectic temperature where delta + melt $\longrightarrow$ gamma) he thought the solubility to be 0.07%. The three solubility points were taken to lie on a straight line.

Lucas[20] and many others have found Fe_3C in ingot iron containing about 0.02% carbon.

Brace and Ziegler[21] used a most improved method of melting with a high frequency bell jar type of vacuum furnace and prepared iron which had a maximum permeability of 25,000 for a zero addition of carbon to the high purity iron. With an 0.06% addition, the maximum permeability was 61,000 while for higher carbon the values dropped. They explained that the high value was due to the correct amount of carbon required to reduce the oxygen content without leaving more than 0.005% carbon in the iron.

Harder and Johnson[22] have shown that the impurities in steel which cause abnormality shift the A_{cm} line to the left but that at high temperatures within the austenitic field the A_{cm} lines converged. The eutectoid point was found to be at about 0.75% carbon instead of 0.85–0.90% carbon.

Grossmann[23] expressed the belief that Fe_3C was soluble in alpha as carbide and estimated its solubility to be about 0.03–0.05% at the temperature of A_1. Gillett's[24] comprehensive discussion of Grossmann's paper brought out considerable data, well illustrated.

It is quite difficult to believe that diffusion takes place as carbide molecules, as stated by Grossmann, instead of as carbon atoms. As the rate of diffusion in steel is rather fast and is greater for smaller sized particles it appears more likely that carbon particles do the shifting through the lattice rather than the large compound.

Gillett[25] published a correlated abstract on the influence of oxygen and nitrogen on the iron-carbon equilibria. Amounts of impurities such as these and perhaps others probably affect the solubility of carbon in alpha to a considerable degree.

It is interesting to note that neither Sauveur[26], Roberts-Austen,[27] Roozeboom,[28] Carpenter and Keeling,[29] Goerens[30] nor Honda[31] showed a carbon solubility field for the alpha phase at the A_1 temperature and below. The diagrams by the Bureau of Standards[32] (Fig. 1), Grossmann,[23] Hanson (refer to footnote 17), Sato,[33] Yensen[34] (Fig. 2) and others show this solubility field.

Recently Yensen[34] stated that iron was non-allotropic when really pure. This was believed because indirect evidence has shown that increased silicon additions raised A_3 and lowered A_4. The evidence of Westgren and Phragmen[1] that alpha, beta and delta were identical led Hanson, in a discussion of the paper to propose the idea that perhaps really pure iron was not allotropic. From Yensen's work it is possible that oxygen and perhaps other impurities, may be responsible for the gamma modification. Yensen's diagram (Fig. 2) shows carbon to be soluble in alpha to about 0.06% at the A_1 temperature.

Recently Daeves[35] published an iron-carbon diagram in which the solubility of carbon in alpha at A_1 is indicated. It is of interest to note that in 1925[36] the same author published a diagram in which the solubility of carbon in alpha at the eutectoid temperature was not recognized.

It is possible that Yensen's MN line and Daeves' PQ line

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[17] D. Hanson, Discussion on paper, "The Solution of Cementite in Alpha-iron and Its Precipitation," by J. H. Whitely, *Journal Iron & Steel Institute*, **116**, No. 2, 305–307 (1927).

[18] G. Masing and L. Koch, "Duraluminartige vergütung bei Eisen-Kohlenstoff-Legierungen," *Wissenschaftliche Veröffentlichungen Siemens-Konzern*, **6**, 202 (1927)

[19] Seiichi Tamura "Notes on Pseudo-Twinning in Ferrite and on the Solubility of Carbon in Alpha-Iron at the A_1 Point," *Journal Iron & Steel Institute*, **115**, No. 1, 747–754 (1927).

[20] F. F. Lucas, "Observations on the Microstructure of the Path of Fatigue Failure in a Specimen of Armco Iron," *Transactions American Society of Steel Treating*, **11**, 531 (1927).

[21] P. H. Brace and N. A. Ziegler, "Application of a High Vacuum Induction Furnace to the Study of Gases in Metals," *Proceedings, Institute of Metals Division, American Institute Mining & Metallurgical Engineers*, **1928**, page 544.

[22] O. E. Harder and W. S. Johnson, "Solubility of Carbon in Normal and Abnormal Steels," *Transactions American Society Steel Treating*, **15**, 49–68 (1929).

[23] M. A. Grossmann, "The Oxygen Dissolved in Steel and Its Influence on the Structure," *Transactions American Society Steel Treating*, **16**, 1–56 (1929).

[24] H. W Gillett, Discussion of Grossmann's paper—reference[23] 29–39.

[25] H. W. Gillett, "Correlated abstracts—The Unknown Influence of Oxygen and Nitrogen on the Iron-Carbon Diagram," METALS & ALLOYS, **1**, 237 (1929).

[26] Albert Sauveur, "The Microstructure of Steel and Current Theories of Hardening," *Transactions American Institute Mining & Metallurgical Engineers*, **26**, 863 (1896).

[27] Sir Roberts-Austen, *4th Report of Alloys Research Com. of the Institute of Mechanical Engineers*, 1897.

[28] Bakhuis Roozeboom, "Iron and Steel from the Standpoint of the Phase Doctrine," *Journal Iron & Steel Institute*, **58**, 311–316 (1900); *Zeitschrift für Physik Chemie*, **34**, 437 (1900).

[29] H. C. H. Carpenter and Keeling, "The Range of Solidification and the Critical Ranges of Iron Carbon Alloys," *Journal Iron & Steel Institute*, **65** 224 (1904).

[30] P. Goerens, "Ueber den augenblicklichen Stand unseres Kentnisse der Erstarungs und Erkältungsvorgänge bei Eisen-Kohlenstoff, *Metallurgie*, **4**, 142–149 (1907)

[31] K Honda, "On the Constitutional Diagram of the Iron-Carbon System Based on Recent Investigations," *Journal Iron & Steel Institute*, **105**, 381–392 (1922).

[32] Bureau of Standards Metallurgical Staff, "Principles of the Heat Treatment of Steel," *Transactions American Society Steel Treating*, **14**, 530 (1928).

[33] Tomoo Sato, "On the Critical Points of Pure Carbon Steels," *Science Reports, Tohoku Imperial University*, **8**, 27–52 (1928).

[34] T. D. Yensen, "Pure Iron and Allotropic Transformations," *Transactions Iron & Steel Division, American Institute Mining & Metallurgical Engineers*, **1929**, pages 320–332 Discussion, 333–349.

[35] K. Daeves, "Das Eisen-Kohlenstoff Diagram," *Berichte* No. 42 *des Werkstoff-Ausschusses, des Vereins Deutscher Eisenhüttenleute*, **1929**, page 8. (Third improved Edition)

[36] K. Daeves, "Das Eisen-Kohlenstoff-Diagram und die wichtigsten Gefügebestandteile der Kohlenstoffstähle," *Stahl und Eisen*, **45**, 427, 434 (1925).

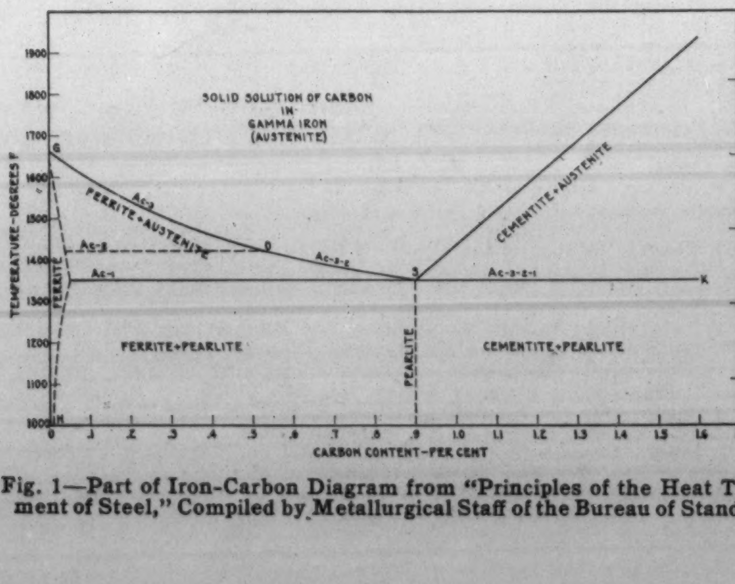

Fig. 1—Part of Iron-Carbon Diagram from "Principles of the Heat Treatment of Steel," Compiled by Metallurgical Staff of the Bureau of Standards

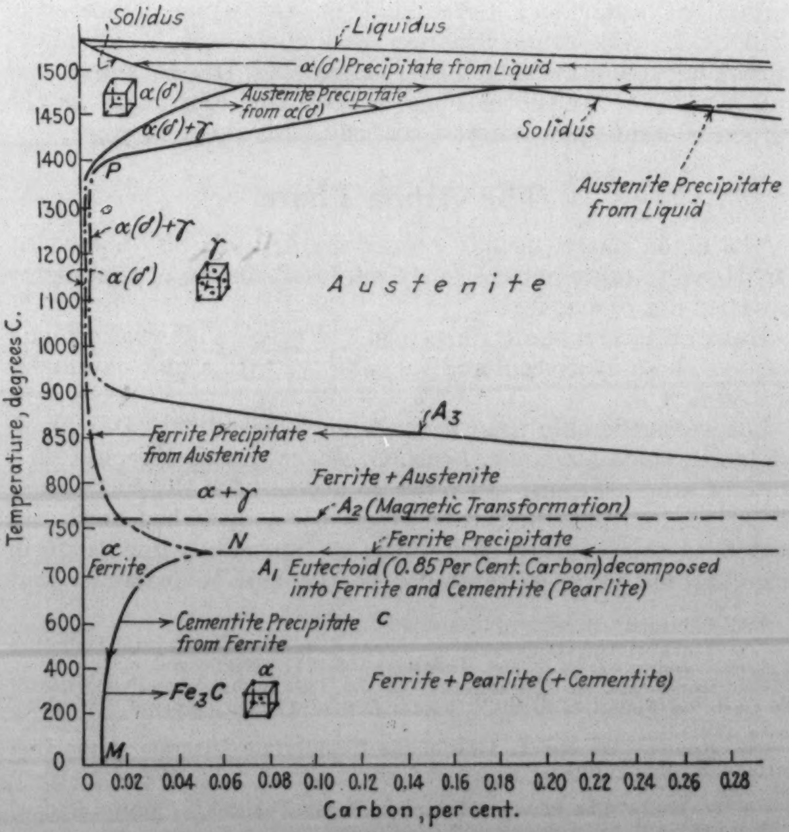
Solidus
Liquidus
L
α(δ) Precipitate from Liquid
α(δ)
Austenite Precipitate from α(δ)
Solidus
α(δ)+γ
P
Austenite Precipitate from Liquid
α(δ)+γ
γ
α(δ)
Austenite
A3
Ferrite Precipitate from Austenite
Ferrite + Austenite
α + γ
A2 (Magnetic Transformation)
N
Ferrite Precipitate
α Ferrite
A1 Eutectoid (0.85 Per Cent. Carbon) decomposed into Ferrite and Cementite (Pearlite)
Cementite Precipitate from Ferrite
C
α
Fe3C
Ferrite + Pearlite (+ Cementite)
M1
Temperature, degrees C.
0
200
400
600
700
750
800
850
900
1000
1100
1200
1300
1400
1450
1500
0
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
0.22
0.24
0.26
0.28
Carbon, per cent.

Fig. 2—Part of Iron-Carbon Diagram Proposed by Yensen

should be straight; most conjugate lines representing *truly* equilibrium conditions are probably straight rather than curved.

The Critical Ranges

The A_1 transformation—One of the early references of interest, that has a bearing on the critical range of an iron wire, is the work of Gore[37] in 1869, in which he stated "whilst making some experiments of heating a strained iron wire to redness by means of a current of voltaic electricity, I observed that, on disconnecting the battery and allowing the wire to cool, during the process of cooling the wire suddenly elongated, and then gradually shortened until it became quite cold." He also tested wires of gold, copper, etc., which did not have the same effect. He did not offer any explanation for his results obtained with the iron wire.

In 1890 Osmond[38] published results on thermal analyses (cooling curves) on extra mild, mild, medium, hard steels and electrolytic iron. He reported the start, maximum and end of the Ar transformations. These values were nearly the same as those obtained at present whith commercial steels. Osmond's bibliography included thirty-nine references to researches on the critical points by the following authors: Tchernoff, Gore, Barret, Sato, Forbes, Smith, Norris, Moissan, Baur, Crystal, Brinell, H. LeChatelier, Pionchon, Tomlinson, Newall, Ledebur and Howe.

In 1896, Sauveur[26] indicated the critical ranges of various iron-carbon alloys on a constitution diagram by broad bands representing a variation of about 50° C.

Roberts-Austen[27] published a constitution diagram from results of cooling curves on 16 iron-carbon alloys, about one-half of which contained over 1.7% carbon. Roozeboom[28] applied the phase rule to Roberts-Austen's scattered data and published an iron-carbon diagram which is quite similar to our present ones.

Carpenter and Keeling[29] ran cooling curves on 38 iron-carbon alloys, of 0.01 - 1.69% carbon, by the differential method which checked the previous work quite well.

Important contributions on the A_1 transformation were made by Heyn, Rosenhain, Benedicks, Charpy and Grenet, Brayshaw and others. Howe[39] found that the equilibrium temperature for A_1, which was designated as Ac_1, occurred between 723 and 724° C. for iron-carbon alloys with low impurities.

Honda[40] studied the Ac_1 and Ar_1 in different carbon steels, having low impurities, by magnetic analysis. Both slow and rapid rates of heating and cooling were used. When the temperature interval between 650 and 800° C. was passed in 9–10 min., the Ac_1 range was 739–760° C. and the Ar_1 was 635–700° C. With 2 - 4 hr. in cooling through the same temperature range, the Ac_1 varied between 725–730° C. while the Ar_1 varied between 688–721° C. He also stated that the thermal change on passing the A_{cm} line was too small to be detected by thermal analysis.

Dejean[41], Portevin and Garvin[42] and Chevenard[43], French and Klopsch[44] and others have shown that with rapid rates of cooling the normal Ar points are lowered to 300° C. and below. Portevin and Garvin called this transformation Ar" (martensite formation). On cooling slower than the critical cooling velocity (6.9 sec. between 700–200° C.) a critical point, designated as Ar", occurred at about 650° C.

It has long been known that the rates of heating and cooling influence the positions of the A_1 transformation. Fast heating raises the point while fast cooling lowers the transformation. Nearly all investigators agree that the eutectoid composition is close to 0.85% carbon.

The A_2 transition—The A_2 or magnetic transition is known as the Curie[45] point or the magnetic transition of ferrite. Above A_2 the iron was formerly called beta iron because it is paramagnetic and not ferro-magnetic.

The work of Burgess and Crowe[46] on thermal analyses showed $A_2 = Ac_2 = Ar_2 = 768°\ C. \pm 0.5°\ C.$ In all but one of 15 samples of high purity electrolytic iron the point occurred within 2–3° C. They included a bibliography of 67 references on critical points of high purity iron.

While the allotropy question of the A_2 point was being seriously debated, Benedicks [47] ran differential dilatation curves with an instrument stated to read accurately to 0.7×10^{-5} mm. He reported a slight but continuous deviation on heating which was very small.

According to Honda's[31] and Okubo's theory, "the gradual diminution of magnetism with the rise of temperature is due to the increasing velocity of rotation of the atoms about their magnetic axes. The angular velocity of rotation is considered to be comparatively small at room temperatures and the gyrostatic resistance to the turning of the magnetic axes of the atoms in the direction of the field is very small. As the temperature is continually increased to a very high degree the angular velocity always becomes greater, and hence, the gyrostatic action of the atoms rapidly increases, the substance becoming, thereby, less and less magnetizable, till magnetization vanishes."

Berliner,[8] Honda[3] and others find that the A_2 transition (maximum) occurs at the same temperature (768° C.) on both heating and cooling when measured thermally. Honda and

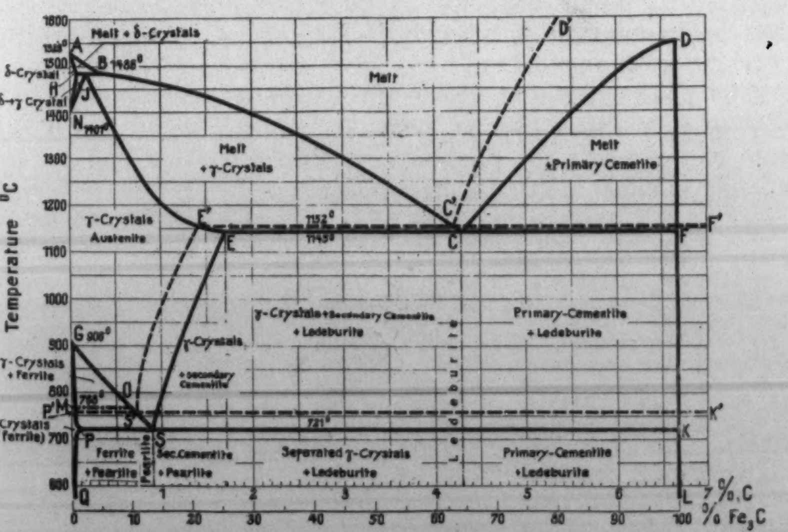

Fig. 3—Iron-Carbon Diagram Proposed by Daeves

Prepared by the Verein deutscher Eisenhüttenleute, 1929

The Iron-Carbon diagram full lines stable. Dashed lines metastable system

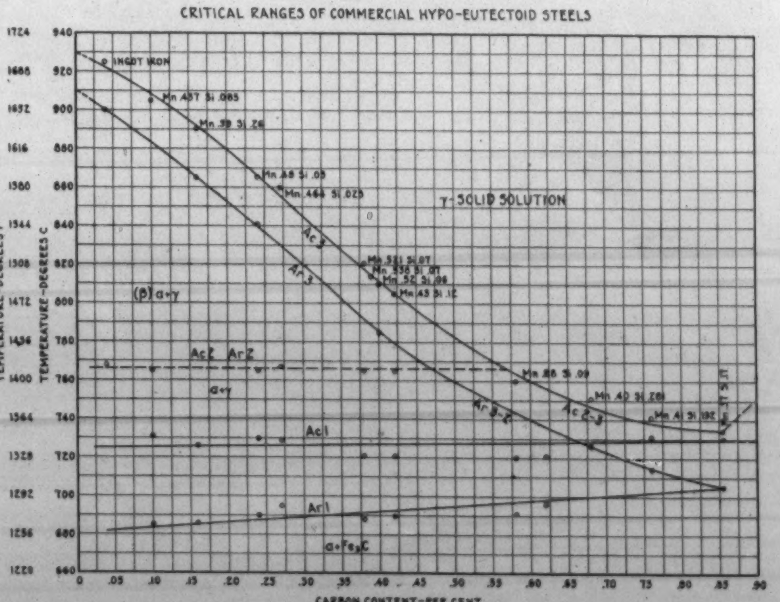

Fig. 4—Hoyt and Dowdell's Modifications of the Critical Ranges of Commercial Hypoeutectoid Steels

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[37] G. Gore, "On the Momentary Molecular Change in Iron Wire," *Proceedings Royal Society* (London), **17,** 260 (1869).

[38] M. F. Osmond, "On the Critical Points of Iron and Steel and Nickel," *Journal Iron & Steel Institute*, **1,** 38–80 (1890).

[39] H. M. Howe, "Ac, the Equilibrium Temperature for A_1 in Carbon Steel," *Transactions American Institute Mining & Metallurgical Engineers*, 47, 740–747 (1913).

[40] K. Honda, "On the Temperature of the Reversible A_1 Transformation in Carbon Steels," *Science Reports, Tohoku Imperial University*, **5,** 285(1916).

[41] P. Dejean, "Les points critiques de refroidissement des aciers auto temperuts et la formation de la troostite et de la martensite," *Revue de Metallurgie*, **14,** 641 (1917).

[42] A. Portevin and M. Garvin, "Experimental Investigation of the Influence of the Rate of Cooling on the Hardening of Carbon Steels," *Journal Iron & Steel Institute*, **99,** 469–563 (1919).

[43] P. Chevenard, "Mechanism of the Quenching of Carbon Steels," *Revue de Metallurgie*, **16,** 17–79 (1919).

[44] H. J. French and O. Z. Klopsch, "Quenching Diagrams for Carbon Steels in Relation to Some Quenching Media for Heat Treatment," *Transactions American Society Steel Treating*, **6,** 251 (1924).

[45] M. P. Curie, "Propriétés magnétiques des corps A diverses températures," *Annales de Chimie et de Physique*, (4) **5,** 289 (1895).

[46] G. K. Burgess and J. J. Crowe, "The Critical Ranges A_2 and A_3 of Pure Iron," *Transactions American Institute Mining & Metallurgical Engineers*, **47,** 665–739 (1913); also *Bureau of Standards, Scientific Papers* No. 213.

[47] C. Benedicks, "Experiments on Allotropy of Iron; Behavior of Ferro-Magnetic Mixtures; Dilatation of Pure Iron," *Journal Iron & Steel Institute*, **89,** No. 1, 407, 459 (1914).

Umino,[48] however, show that the maximum physical effect when measured magnetically and with a calorimeter, respectively, occurs at about 790° C.

This transition point is probably similar in nature to that of A_0 and is apparently different from the A_3 transformation in that there is no change in the type of crystal lattice. Westgren[49] X-rayed nearly pure iron at between 800–830° C. in the so-called "beta" region and concluded that "Within the so-called beta iron interval, the iron atoms are oriented in exactly the same way as in alpha iron."

The allotropy question of beta iron resolves itself into one of definition; if no recrystallization results on changing from alpha to beta, or vice versa, it is not considered to be an allotropic modification.

The A_3 transformation—A large number of investigators have determined the critical points, A_1, A_2 and A_3 of iron-carbon alloys. In addition to the work previously mentioned, Howe,[50] Burgess and Crowe,[46] Guillet and Portevin,[51] Carpenter[52] and Wever[53] reported that the beginning of Ac_3 for nearly pure iron was about 900° C. when heated at 2–9 sec. /° C. The gap between Ac_3 and Ar_3 varied from 31–36° C. and depended on the rates of heating and cooling.

The general methods used by various investigators consisted of thermal analysis, dilatation, thermoelectric, crystallographic, mechanical properties, electrical resistance, magnetic and calorimetric.

Honda[54] found the Ac_3 point in iron to be 903° C. when determined by magnetic analysis. Burgess and Kellberg[55] found Ac_3 and Ar_3 to begin at 894° C. with an electrical resistance method and that each extended over a temperature range of 25° C. Esser[56] used Portevin and Chevenard's dilatometric method and found Ac_3 = 906° C. and Ar_3 = 897° C.

Hoyt and Dowdell[57] determined the critical ranges for commercial hypo-eutectoid steels (Fig. 4) by differential thermal analysis (about 20 sec./° C.). The A_3 points were also checked by heat treatment and microscopic analysis of very small specimens. Theoretically all of the lines in the figure should be straight.

The question as to whether carbon or carbide is dissolved in the gamma phase has long been debated. Sauveur[58] published the answers of 23 eminent metallurgists on this and other questions; most of the answers, however, were a matter of opinion without a great deal of experimental evidence.

Westgren[59], Dowdell and Harder,[60] calculated the density of several retained austenites from X-ray diffraction patterns and stated that carbon is within the face-centered cubic lattice of gamma but does not replace iron atoms in the lattice. It is quite unlikely that the large unit crystal of cementite (4 Fe_3C) occurs in austenite in a state of solid solution. Why not postulate that forces exist between the carbon and iron atoms which allow Fe_3C to precipitate after recrystallization from gamma to alpha?

Schwartz, Payne, Gorton and Austin[61] have given the name "Boydenite" to a solid solution of carbon in gamma iron and believe that austenite is a solid solution of carbide in gamma iron. The maximum solubility of carbon in gamma was stated by Gutowsky[62] to be 1.7% at a temperature of 1130° C. Others have not found values differing appreciably.

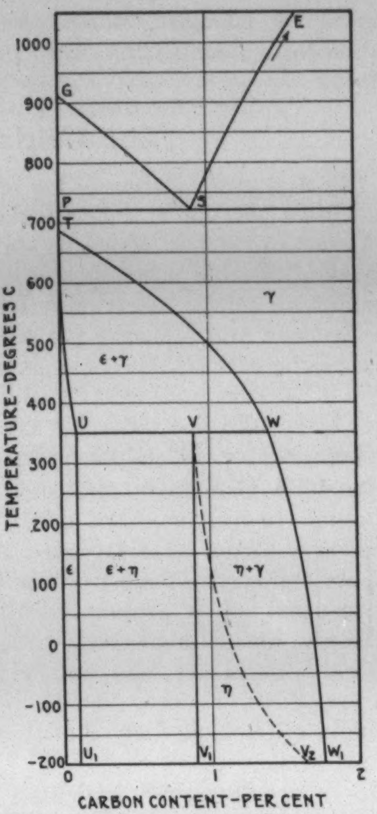

Fig. 5—Hanneman and Schrader's Proposed but Unconfirmed Modification of the Metastable Iron-Carbon Diagram for Fast Cooling Rates

The Delta Phase

The A_4 or the gamma-delta transformation was first observed by Osmond.[63] Later Curie[45] found it by magnetic analysis. Gontermann[64] did considerable work on this transformation and found an arrest at 1411° C. with an 0.07% carbon iron. Weiss and Föex[65], Ruer and Kaneko,[66] Ruer and Fick[67] and Ruer and Klesper[68] found the Ar_4 and Ac_4 at 1400 and 1410, respectively. Ruer and Kaneko stated that A_4 rose rapidly with an increase of carbon and that 1486° C. was the peritectic temperature horizontal. The composition of delta at this temperature was 0.07% carbon. The A_4 region shown in Fig. 3 was apparently drawn from Ruer's data.

Sato[69] determined dilatation curves of the A_3 and A_4 transformations and found that during heating the high purity iron contracted at Ac_3 but expanded at A_4. The ratio of the magnitude of the length change due to the A_3 and A_4 transformations is about 10:3. The thermal dilatation curve of delta iron formed the continuation of that of the alpha phase showing, as they stated, that delta iron is the same phase as alpha iron.

Westgren and Phragmen[1] X-rayed a high purity iron at 1425° C. (delta). The glowing wire was rotated and gave a typical body centered cubic pattern with a lattice parameter of 2.93 A. U At 800° C. (so-called beta) the value was 2.90 A. U. and the alpha phase at room temperature gave 2.83 A. U.

The researches of Sato and Westgren and Phragmen indicate that iron has a strong tendency to remain in the body centered cubic lattice. The diagram proposed by Yensen[34] has considerable merit and deserves more study to find the reason for the face-centered modification and the proof of the non-allotropy of really pure iron.

The So-called "Epsilon and Eta" Phases

Hanemann and Schraeder[70] concluded that the "Fer de Lance" martensite-austenite equilibria could be represented by a diagram so they proposed the metastable diagram shown in Fig. 5. The assumption involved in the diagram required that there should be a critical on quenching pure iron at about 685° C. They found such a thermal effect with Krupp iron (0.07% carbon) at about 685° C. No certain confirmation of this has been obtained in unpublished work by other observers, working with purer iron, who have attempted to confirm it.

The concentration of carbon was assumed to be 0.10% at U, 0.89% at V and 1.40% at W. The authors claim that if the rate of quenching for steels of less than 1.40% carbon is fast enough to eliminate the Ar_1 transformation, epsilon will separate from the gamma at some temperature along the line TW, depending on the carbon content of the steel. When the temperature of 350° C. is reached they believe that epsilon of 0.10% carbon reacts with gamma of 1.40% carbon to form eta (martensite). This reaction is supposed to go to completion if the composition of the steel is 0.89% carbon.

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[48] S. Umino, "On the Heat of the A_2 and A_3 Transformations in Carbon Steel," *Science Report, Tohoku Imperial University*, **16**, 1009 (1927).

[49] A. Westgren, "Roentgen Spectroscopic Investigation of Iron and Steel," *Journal Iron & Steel Institute*, **103**, 303–325 (1921)

[50] H. M. Howe, "Discussion of Existing Data as to the Position of Ac_3," *Transactions American Institute Mining & Metallurgical Engineers*, **47**, 587–746 (1913).

[51] L. Guillet and A. Portevin, "Sur quelques propriétés d'un fer electrolytique industriel," *Comptes Rendus*, **156**, 702 (1913).

[52] H. C. H. Carpenter, "The Critical Ranges of Pure Iron with Special Reference to the A_2 Inversion," *Journal Iron & Steel Institute*, **87**, 315–326 (1913).

[53] F. Wever, "Zur Thermodynamik der Umwandlungen des Eisens," *Mitteilungen Kaiser-Wilhelm Institut für Eisenforschung in Düsseldorf*, **9**, 151 (1927).

[54] K. Honda, "On the Magnetic Study of the A_3 Transformation in Pure Iron," *Science Report, Tohoku Imperial University*, **4**, 261 (1915).

[55] G. K. Burgess and I. N. Kellberg, ""Electrical Resistance and Critical Ranges of Pure Iron," *Scientific Papers, Bureau of Standards*, No. 236, 1914.

[56] Hans Esser, *Stahl und Eisen*, **47**, 337 (1927).

[57] S. L. Hoyt and R. L. Dowdell, "Metals and Common Alloys," McGraw-Hill Book Co., 1st edition, 1921.

[58] A. Sauveur, "The Current Theories of the Hardening of Steel 30 Years Later," *Transactions American Institute Mining & Metallurgical Engineers*, **73**, 859–902(1926.) Discussion 902–908.

[59] A. Westgren and G. Phragmen, "X-ray Studies on the Crystal Structure of Steel," *Journal Iron & Steel Institute*, **109**, Pt. 2, 159–174 (1924).

[60] R. L. Dowdell and O. E. Harder, "The Decomposition of the Austenitic Structure in Steels, Part V. X-ray Studies," *Transactions American Society Steel Treating*, **11**, 959 (1927).

[61] H. A. Schwartz, H. R. Payne, A. F. Gorton and A. A. Austin, "Condition of Stable Equilibrium in Iron Carbon Alloys," *Transactions American Institute of Mining & Metallurgical Engineers*, **68**, 916–929 (1923).

[62] N. Gutowsky, "Zur Theorie des Schmelz- und Erstarungsprozesses der Eisen-Kohlenstoffliegerungen," *Metallurgie*, **6**, 731 (1909).

[63] M. Osmond, Discussion of paper "On the Changes in Iron Produced by Thermal Treatment," by E. J. Ball, *Journal Iron & Steel Institute*, **1**, 102–105 (1890).

[64] W. Gontermann, "Bemerkungen zum System Eisen-Kohlenstoff," *Zeitschrift für Anorganische Chemie*, **59**, 378–384 (1908).

[65] P. Weiss and G. Föex, *Archives des Sciences physique et naturelles, Geneva*, **31**, 89–117 (Feb. 1911).

[66] R. Ruer and K. Kaneko, "Das System Eisen-Kobalt, *Ferrum*, **11**, 33 (1913).

[67] R. Ruer and K. Fick, "Das System Eisen-Kupfer," *Ferrum*, **11**, 39 (1913).

[68] R. Ruer and R. Klesper, "Die gamma-delta Unwandlung des Reineneisen und ihre Beeinflussung durch Kohlenstoff, Silizium, Kobalt, und Kupfer," *Ferrum*, **11**, 257–261 (1914).

[69] Seikichi Sato, "Dilatometric Investigation of the A_3 and A_4 Transformation in Pure Iron," *Science Report, Tohoku Imperial University*, **14**, No. 5, 513–527 (1925).

[70] H. Hanemann and M. A. Schraeder, "The Structure of Mar tensite," *Transactions American Society Steel Treating*, **9**, 168–233 (1926).

As peritectic reactions are known to be quite sluggish, it is very unlikely that a peritectoid reaction of this type can take place within the short time involved during quenching. On ageing it is also unlikely as atomic mobility is greatly reduced.

Conclusions

It is realized that this abstract is far from complete; many investigators have not been given due credit for their contributions, while others have been omitted for the purpose of brevity only. The field of iron-carbon equilibria, however, is still open for extended research on the effect of impurities on the solubility of carbon in the different phases, on the physical nature of these phases, and on the mechanism involved in the magnetic transition point of iron.

A Welcome New Publication

With March 1930 appeared Vol. 1, No. 1, of *The Steel Founder*, a new publication devoted to the production and sale of steel and alloy castings of all kinds. This periodical is published by the Steel Founders' Society of America, Inc., to encourage cooperation, improve conditions, broaden the markets and generally promote the welfare of all in the industry including the users of steel castings.

Copies of *The Steel Founder* will be sent upon request to anyone interested in the progress and development of the steel foundry industry. Address, Executive Offices, Room 932, Graybar Building, 420 Lexington Ave., New York, N. Y.

The A. S. S. T. Campbell Memorial Lecture

The American Society for Steel Treating's Edward De Mille Campbell Memorial Lecture will be presented this year at the Twelfth Annual National Metal Congress by Marcus A. Grossmann, chief metallurgical engineer of the Central Alloy Steel Corporation, Canton, Ohio, W. H. Eisenman, secretary of the Society, announced recently. The Campbell Lecture has become a major event in the technical programs of every National Metal Congress. The subject of the lecture will be announced later.

The National Metal Congress and the National Metal Exposition will be held this year in Chicago during the week of September 22nd. The Campbell Lecture will be delivered on September 24th at the Stevens Hotel before the annual meeting of the Society.

Mr. Grossmann is the author of numerous technical papers and is co-author of "Physical Metallography." He was graduated from the Massachusetts Institute of Technology in 1911 with the degree of Bachelor of Science, and after a year of teaching, was successively connected with the Pittsburgh Testing Laboratories, Vanadium Corporation of America, U. S. Bureau of Standards, Electric Alloy Steel Co., Atlas Steel Corp., United Alloy Steel Corp., and since 1926, with the Central Alloy Steel Corp.

Marcus A. Grossmann

Nickel Cast Iron News, Vol. 1, No. 1

The first issue of *The Nickel Cast Iron News*, published by the International Nickel Company, Inc., 67 Wall Street, New York, N. Y., appeared in April, 1930. It is printed to resemble a newspaper and contains both information and advertisements on Nickel Cast Iron. It will also have a "Question & Answer" Section.

Link-Belt Company, of Chicago and Philadelphia, will have a very interesting and educational exhibit at their booths, Nos. 256 & 258, aisle one, at the American Foundrymen's Convention, Public Auditorium, Cleveland, Ohio, May 12th to 16th.

One of its outstanding features will be a moving Mold Conveyor, full size, in operation.

A Link-Belt Vibrating Shake-Out Screen will also be shown in operation, as will miscellaneous other equipment for the preparation and handling of sand, and mold and castings handling.

Link-Belt's new Foundry Book No. 1090, will be distributed for the first time at this exhibit.

J. G. Pearce, Director and Secretary of the British Cast Iron Research Association, has been chosen to present the annual exchange paper of the Institute of British Foundrymen before the May meeting of the American Foundrymen's Association. His paper will be on Correlation of Tests for Cast Iron, a subject on which he is one of the world's foremost authorities, as his organization has made this one of its chief fields of recent research.

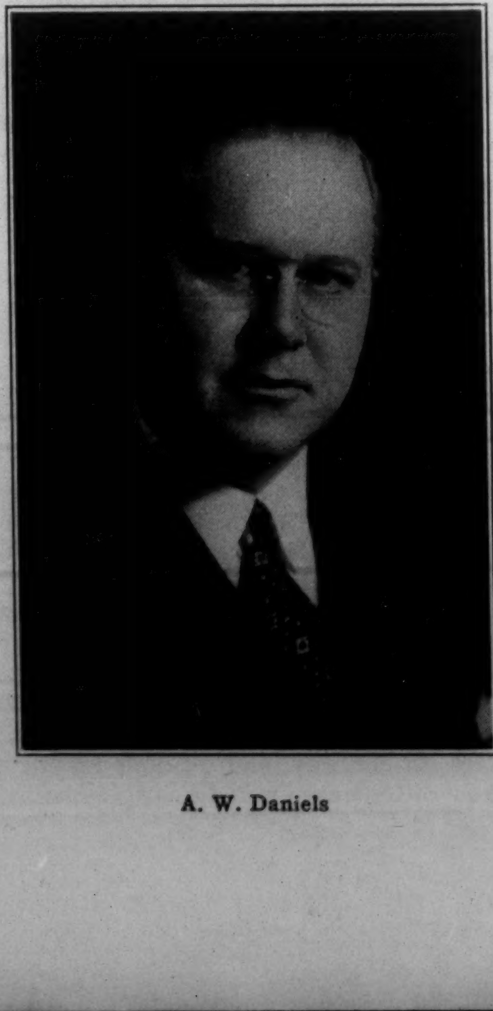
The National Bronze and Aluminum Foundry Co., Cleveland, Ohio, has just completed the largest single unit ever built in the world for the production of aluminum, and has a daily capacity of 150,000 lbs. The furnace itself weighs over 175 tons and required seven months to build. It is operated entirely mechanically, the raw material being charged at one end and the finished product delivered at the other.

A. W. Daniels in Charge of Sales

The American Manganese Steel Company announces the election of Mr. A. W. Daniels as Vice-President in Charge of Sales, effective March 26, 1930.

For seven years prior to entering the employ of the American Manganese Steel Company as Assistant to the Industrial Engineer at the Chicago Heights Plant, Mr. Daniels traveled extensively as a commercial representative. In 1920 he became the AMSCO Chicago Office Manager, a position that put him in intimate contact with the voluminous details of the Manganese Steel business. Two years later he was promoted to Central Sales Manager, which position he occupied but one year before his appointment in 1923 as General Sales Manager of the American Manganese Steel Company.

Mr. Daniels is an authority on the markets and marketing of Manganese Steel and is in complete touch with the developments of the industrial world as applied to the products of the American Manganese Steel Company, and because of his close personal contact with the leaders of Industry, and his keen analysis of business conditions, he is well fitted by experience and knowledge to fill this new position.



A. W. Daniels

Critical Abstract

Dr. Gillett, the editorial staff and specially selected contributors will prepare abstracts of a critical nature on articles of special importance. The current literature will be covered in the Abstracts of Current Metallurgical Literature.

A Study of the Ikeda Short-Time Resistance Test for Fatigue

A study of the Ikeda short-time (electrical resistance) test for fatigue strength of metals. H. F. Moore and S. Konzo, *University of Illinois, Bulletin* No. 33, vol. **27**, Apr. 15, 1930, Engineering Experiment Station, *Bulletin* No. 205.

The figures obtained in the University of Illinois tests of the Ikeda method have been given by Professor Moore in METALS & ALLOYS, vol. **1**, Aug., 1929, page 70, and page 195, October. Ikeda's own work was abstracted in vol. **1**, July 1929, page 195. This new Bulletin gives the details of the work and the curves for the 8 alloys tested.

The reviewer, because of sad personal experience with the rise-of-temperature method on hard, spring-tempered steels, is always from the geographical center of the State of Missouri in regard to accelerated testing for endurance limits. He demands, before he will be willing to trust a rapid method, that the curves be such that one doesn't have to be a clairvoyant or know the answer ahead of time, to tell what point to pick on a curve as being the inflection that denotes the endurance limit. He will, therefore, comment on the Moore and Konzo bulletin from that point of view.

Moore and Konzo have improved the Ikeda method by using the Illinois rotating spring type of testing machine in which one end of the specimen is stationary so that soldered leads can be used. They took rise-of-temperature data simultaneously with the resistance measurements of the Ikeda method. The curves of the rise-of-temperature method for 0.52 carbon steel, brass (second run), copper (second run) do need a clairvoyant, that on carbon tool steel probably would if there more points on the curve, and on one lot of Monel metal, the break is clear, but the value is way on the unsafe side.

The resistance method curves for Armco, 0.20 carbon and 0.52 carbon steels show sharper breaks than the rise-of-temperature curves, and the first and second runs on brass are also sharp. Since the first run was stressed so high that incipient damage probably resulted by over-stressing, it is a question whether the good agreement of the two curves is an argument for the method. It might indicate that the method was insensitive to damage that would show up in a true endurance test. The curve for tool-steel (of 130,000 lbs./in.² endurance limit in a true endurance test) is not satisfying. The curve, with only three points below 130,000 lbs./in.² is not a straight line. The data indicate to the reviewer that very much more would have to be done on hard steels to allow one to judge what stress to take as the endurance limit.

The interesting and illuminating data appear in the runs on Monel and annealed copper. During the test, the energy absorbed raises the temperature of the test piece, as is shown by the rise-of-temperature observations. One would expect that the resistance would rise also, and it does in the steels and the brass. In the Monel and copper, however, it falls at first and then rises. The reversal of slope naturally gives a fairly sharp point, and it happens that the stress at that point coincides as well as one could expect with the endurance limit as determined by regular endurance tests up to 700 million cycles on one lot of Monel, 450 million on another and 400 million on copper. (The specimens in the regular endurance tests on two of these three all fractured so whether they have an endurance limit or not is still a question. The values with which the breaks in the resistance curves correspond are those for which the material will stand half a billion or a billion cycles.)

Just to make the thing more interesting, a second run was made on the over-stressed copper, and its resistance did not fall this time.

These peculiar phenomena call for comment and get it. Moore and Konzo point out that if resistance is affected by repeated stress in one way, and by temperature in another, the negative slope of the curve would be explained by the assumption that in the alloys showing it, the effect of stress over-balances that of temperature at low stresses. One possible assumption is that the negative slope of the resistance curve is due to release of internal stress (even in annealed copper). No curves are given for second runs on Monel but the statement is made that even a fourth test on the same specimen shows a decreasing resistance at the lower stresses in the beginning of the test. It is said that this drooping curve may obscure any definite break in the curve, and render it impossible to pick up the endurance limit in some alloys.

In a footnote to his paper at the Detroit A. S. T. M. meeting in March, Professor Moore[1] states that since Bulletin 205 was issued, tests have been made by the Ikeda method on heat-treated alloy steel, cast iron and duralumin. The Ikeda test shows no clear endurance limit for duralumin, which, Moore states, has no clear endurance limit by long-time tests either. However, against this must be put the fact that for Moore's lot 111 of Monel, which showed no endurance limit by long-time tests, the Ikeda method did show one.

The rock on which all rapid methods have foundered so far is that whatever they show is a result of general slip and not of the start of a crack. Since fatigue failure comes from a crack that starts at some tiny point, the accelerated methods might pass, as up to quality, material that would fail in a true endurance test because of tiny local imperfections. Moore states that the method should have further trial before this question can be settled.

To the reviewer, the value of the work described in the bulletin rests more in the finding of the odd behavior of Monel and copper in the resistance tests than in promising a rapid method of testing for endurance limit. Moore and Konzo claim nothing except that the method has some promise. They do not claim that the promise has yet been fulfilled. It is to be hoped that the work can be continued and extended.—H. W. G.

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[1] Moore, H. F. "Recent Progress in Tests for Automotive Materials," A. S. T. M. Meeting, *Preprint* No. 19, **1930**, page 25.

The Cold Metal Process Company had Dr. George L. Clark, Professor of Chemistry, University of Illinois, discuss his X-ray research work on rolled metals in the Assembly Room of the Dollar Savings & Trust Bank, Youngstown, Ohio, on Friday, April 25, 1930.

About 200 men interested in the working of metals heard this very interesting report entitled "What X-rays are Doing for the Metallurgical Industry." Dr. Clark examined the product of various types of mills, including Cluster mills, 4-high and 2-high mills and the Steckel mill and gave his observations as to the relative merits of the straight rolling and the combined rolling and drawing insofar as these processes affect the products. The results of Dr. Clark's work emphasize the necessity of taking the methods of working into consideration when specifying heat treatments.

After a luncheon at the Century Club as the guests of the Cold Metal Process Company, Dr. Clark invited those attending to take part in a general discussion of his work to-date. Later in the afternoon the visitors were taken to the plant of the Company to see the Steckel Mill in operation.

Oxweld Acetylene Company, 30 East 42nd St., New York, has recently announced another new blowpipe which is compact and light. With their No. 4 welding head it weighs but 24 ounces. The long thin shape of the welding heads makes it possible for this blowpipe to be used in places inaccessible to almost any other type of equipment. The inner cone of the flame is somewhat different from that obtained with any other blowpipe. It is shorter and thicker and has a tendency to assume the shape of a ball at the end. This speeds up the rate of welding because a larger portion of the high temperature flame (or inner cone) surface is brought closer to the metal.

Abstracts of Current Metallurgical Literature

In this section, abstracts of metallurgical articles in various publications will appear. These abstracts are not critical, but merely review developments as they are recorded. Every effort will be made to report on all articles as soon as possible.

GENERAL

The Contributions of Manchester Researches to Mechanical Science. R. W. Bailey. *Proceedings, Institution of Mechanical Engineers,* 1929, No. 4, pages 613–683.

General summary of scientific advancement in Manchester, including metallurgy and related subjects. Bibliography of 111 references, pages 667–675. Discussion, pages 676–683. RHP

Development Program May Restore Prestige of Cast Iron. L. W. Spring. *Iron Trade Review,* Nov. 14, 1929, Vol. 85, pages 1240–1241.

Paper before Chicago Section of the American Chemical Society. Properties of cast-iron which make it useful for certain purposes for which steel is unsuitable are: high fluidity, low shrinkage, easy machining and greater resistance to rusting and ordinary corrosion. Chief objections are a relatively low tensile strength and great brittleness under shock or overload. Various varieties such as gray iron, semi-steel, and chilled iron are made by varying the silicon content, and controlling the rate of cooling of the molten metal, thus controlling the amount of free graphite. The higher the silicon and the slower the cooling, the softer the iron will be. Malleable cast-iron requires accurate regulation of production processes and annealing. Pearlitic cast-iron, produced by several different processes, is a newcomer among the types of cast-iron. Each of these varieties has particular advantages. Gray Iron Institute, Inc. has been organized for a development campaign. MS

What a Heat Treater Should Know about Metallurgy. George M. Enos. *Fuels & Furnaces,* Oct. 1929, Vol. 7, pages 1521–1525.

Fundamental information which a heat treater should have includes some knowledge of chemistry, pyrometry, steel-making processes, hot working of steel, fuels and furnaces, physical testing and physical metallurgy. MS

Materials of Construction for Chemical Engineering Equipment. Editorial Supplement of Sept. 1929 issue of *Chemical & Metallurgical Engineering,* 40 × 28 inches.

Properties of the following materials is presented in table form: corrosion, heat and abrasion resistant material; non-metallic materials; wood; enameled steels; chemical stoneware; compounded asbestos materials; cements.

The Constitution of Steel and Cast Iron, Section II—Part XIII. F. T. Sisco. *Transactions American Society for Steel Treating,* Dec. 1929, Vol. 16, pages 950–959.

This installment, the twenty-third of a series, deals with heat treatment as applied in cold-working processes, particularly wire drawing. Annealing below the critical range, patenting, and oil tempering are described. The deleterious effect of hot galvanizing upon the mechanical properties of high strength wire is also considered. WHK

PROPERTIES OF FERROUS ALLOYS

Investigations on Tungsten Steels. (Untersuchungen über Wolframstahl.) W. Zieler. *Archiv für das Eisenhüttenwesen,* July 1929, Vol. 3, pages 61–78. Also *Stahl und Eisen,* July 25, 1929, Vol. 49, pages 1083–1084; *Iron Age,* Dec. 12, 1929, page 1595.

The investigation was made to determine the reason for failures of tungsten steels. Four different groups with carbon contents of 0.3%, 0.7%, 1.1% and 1.4% with tungsten contents of approximately 1%, 5%, 10%, 15% and 20% in each group were examined by microscopic, dilatometric and hardening tests. The line of carbon solubility in tungsten steels according to Oberhoffer, Daeves and Rapatz is confirmed as well as the distinction between the stable and metastable system Fe–W–C, as given by Hultgren. Guillet's diagram of tungsten steels is wrong. The shape of the carbides depends very much upon the heat treatment and velocity of cooling. The structure of the various types of tungsten steels is discussed in detail. The result of the dilatometric tests is as follows: the A_3 transformation rises with increasing tungsten content in the low carbon alloys (up to 0.3% C). The transformation is no more clearly observed in the steels with 15–20% tungsten. Ac_1 and Ac_3 are practically constant for steels with medium and high carbon content. Ar_3 and Ar_1 are generally lowered with increasing amounts of tungsten. A steel with 1.4% C and 15 or 20% W hardened in air. The results of hardening tests are briefly summarized in the following table:

Group: 0.3% C Hardening medium: Oil

% Tungsten	0	1	5	10	15	20
Highest Brinell number	311	311	425	343	401	321
Quenching Temperature ° C.	1200	1250	1050	1150	1250	1200

Group: 0.3% C Hardening medium: Water

Highest Brinell number	447	495	506	290	262	212
Quenching Temperature ° C.	880	900	900	880	900	820–900

Group: 0.7% C, Si: normal. Hardening medium: Oil

% Tungsten	0	1	5	10	15	20
Highest Brinell number	305	712	627	653	627	627
Quenching Temperature ° C.	950	850	1000	1000	1000	1100–1300

Group: 0.7% C, Si: high (0.5–0.9%). Hardening medium: Oil

Highest Brinell number	305	550	630	534	500	510

As can be seen from the table, a higher silicon content lowers the hardness. The following table proves that a high hardness can be obtained with high carbon and tungsten content at very low quenching temperatures (750–800° C.).

Group: 1.1% C. Hardening medium: Oil

% Tungsten	0	1	5	10	15	20
Highest Brinell number	578	555	601	601	601	653
Quenching temperature ° C.	1250	1250	950	1050	1050	1050

Group: 1.4% C. Hardening medium: Oil

Highest Brinell number	534	534	601	682	712 750	712 750
Quenching temperature ° C.	900	800	850	800 to	950 to	1100

The steel 1.4% C, 20% W was successfully applied for cutting chilled cast iron with a low cutting speed of 4 m. per min. This steel could be furthermore improved for this purpose by adding 0.6–0.7% Cr. A survey of the available literature is given. GN & VSP

Hot-Yield Point and Hot-Tensile Strength of Boiler Materials. (Warm-Streckgrenzen und Warm-Fertigkeiten der Kesselbaustoffe.) Fr. P. Tische & V. Ehncke. *Krupp'sche Monatshefte,* Dec. 1929, pages 209–211.

ischer

Ehmcke

A revised tabulation for yield point and tensile strength of boiler steels between 20 and 500° C. is given, according to the specifications of the German "Vereinigung der Grosskesselbesitzer." The table holds good for ordinary as well as Izett Steel No. 1–4. GN

Secrecy Stays Die-Casting Process. S. Tour. *Iron Age,* Jan. 3, 1929, Vol. 123, pages 52–53.

Dies for pressure casting of aluminum fail from warpage and dimensional changes, also from heat-checking, a fatigue phenomenon. Thermal expansion and contraction of the surface layer of the die in contact with the casting produces repeated stresses which result in alligator cracks. Dies of chromium-vanadium steel would produce 10,000 to 20,000 waffle grids, while 50,000 to 100,000 may be expected from new steels, of which "hundreds" have been tried. The only inkling of the composition of the new steels is that they may contain nickel, or "considerable" tungsten and chromium.—*From abstracts prepared by the A. S. T. M. Committee on the Fatigue of Metals.*

Alloys with High Permeability. (Les alliages a haute permeabilite.) M. Chauchat. *L'Industrie Electrique,* Dec. 10, 1929, Vol. 38, pages 539–545; *Bulletin Société Francaise des Electriciens,* Oct. 1929, Vol. 9, pages 1091–1106.

The requirements to which alloys with high permeability must correspond are outlined. Permaloy A and Mumetal (78.5% Ni) and Permaloy B Radio metal, Permax (40–60% Ni) are compared in electrical properties with soft steel, 2% and 3½% Si steels. High permeability metals are made from Swedish iron and electrolytic Ni in induction furnaces observing all precautions to prevent the contamination of the melt with C, S and O_2. Before annealing the permeability is barely 5–15% of the final. Much care must be paid to prevent contamination in annealing usually conducted in containers with 2 lids the space between which is filled with iron oxides. Temperature limits are 900–950° C. The metal is kept at it at least 2 hours. Cooling must be slow, especially in the 900–2300° range taking at least 8 hours. Second annealing at 600° followed by slow cooling is sometimes advantageous. Repeated annealing can only improve these alloys. JDG

CORROSION, EROSION, OXIDATION, PASSIVITY AND PROTECTION OF METALS AND ALLOYS

The Significance of Corrosion Research. *Refrigeration Engineering,* Feb. 1930, Vol. 19, pages 61–62.

An interesting review of the results of research work done by a committee of the American Society of Refrigerating Engineers in an attempt to cut down the ravages of corrosion in refrigerating plants. This is a good illustration of the investment value of a certain expenditure of time and money on a definite problem of this kind. Approximately $8000 was raised and a certain amount of volunteer time contributed by a few members of the committee for a period of two years. The author of this article states that as applied to ice cans alone, their life has been doubled and that this means an annual saving of about one million dollars a year or more. However, the work was started more to protect uncoated pipe and tanks and corrosion has been practically stopped on such material exposed to circulating brine. The absence of any difficulty due to the poisonous nature of dichromate by the use of a simple measure of cleanliness by the workman is mentioned.—*National Tube Company Abstract Bulletin.*

Optical Investigations of the Passivity of Metals. L. Tronstad. *Nature,* Sept. 7, 1929, Vol. 124, page 373.

The state of polarization of light reflected from mirrors of iron and nickel passive and activated, indicates that in the activated state the oxide film is porous.—*Abstract Bulletin Kodak Research Laboratories.*

Prevention of Corrosion of Lead in Buildings. *Bulletin* No. 6, *Department of Scientific & Industrial Research,* 4 pages.

The Bulletin briefly summarizes the results of some investigations into the corrosion of lead in buildings. Particular attention is paid to methods for preventing possible decay of the metal when it is used in contact with cement or lime mortar or plaster, with timber or with soil. The Bulletin abstracted from Technical Paper No. 8, "The Corrosion of Lead in Buildings."

Corrosion and Pipe Line Coverings. C. Fitzgerald. *Preprint American Petroleum Institute Meeting,* Dec. 5, 1929, 7 pages.

Soils corrosive to bare pipe are generally destructive to bituminous or asphaltic coatings. Such coatings do not remain on the pipe. This is often due to soil stresses. Wrapping the coating allows the soil stress to be exerted on the wrapping, with less destruction of the coating. Non-corrosive soils demand no protective coating. Extremely corrosive ones demand extra precautions, such as placing the pipe and its protective coatings in a red wood box, or using a concrete envelope. In moderately corrosive soil, the choice of a coating that will economically justify its use, is a difficult matter as so many factors enter in. Very interesting illustrations of deteriorated coatings are shown. HWG

Pipe Line Currents. K. H. Logan, W. Rogers & J. F. Putnam. *Preprint American Petroleum Institute Meeting,* Dec. 5, 1929, 6 pages.

In earlier times, much corrosion of pipe lines for oil, gas and water was thought to be due to "stray current" electrolysis, due to leakage of d. c. from electric railways. The situation has been under study by the Bureau of Standards for many years. It is found that pipe lines often carry currents in such localities that leakage could not possibly occur. Moreover, these currents do not fluctuate as those leakage currents would. The soils and the pipes appear to form huge galvanic cells, in some cases; in others, no adequate explanation has been adduced. There is considerable correlation between the locations where the "pipe line current" leaves the pipe, and corrosion and resulting leaks. Currents up to 5 amperes have been measured. The effect of such currents has not been sufficiently established to justify excessive precautions to prevent them. If their prevention can be accomplished simply and cheaply, it would be wise to take such precautions. Use of high resistance metal in pipes, insertion of insulating joints and surface insulation by non-conductive protective coatings are suggested as preventives. HWG

The Corrosion of Lead in Buildings. *Technical Paper* No. 8, *Department of Scientific & Industrial Research,* 30 pages.

The present report is an attempt to summarize some previous observations on the problem, to record the results of investigations into the mechanism of corrosion, and, lastly, to suggest the remedial measures appropriate to each case. The contents are as follows: Part I—Corrosion Caused by Cements and Mortars: General Description of the Effects observed, Cause of the Corrosion, Methods of Prevention. Part II—Corrosion Caused by Timber: General Description of the Effects Observed, Cause of the Corrosion, Tests on the Corrosion of Lead by Timber, Methods of Prevention. Part III—Corrosion Caused by Soil: General Description of the Effects Observed, Cause of the Corrosion, Methods of Prevention.

Corrosion of Metals and Alloys. (La Corrosion des metaux et alliages.) Albert Portevin. *Revue de Metallurgie*, Nov. 1929, Vol. 26, pages 606–631. Dec. 1929, pages 635-654.

Corrosion effects are either the reduction of the useful cross-section of the metal or the changes in its physical properties. The uniform solution removes the metal gradually, parallel to its surface. The speed of it depends on the shape of the surface. It takes place usually in strong solvents. Localized corrosion is characterized by non-uniform depth of attack and cannot be defined by the loss per unit of area. The difference of attack on adjoining areas might be considered as a suitable criterion for this type of corrosion. Rusting of steel is an example of it. Internal corrosion does not destroy the surface of an object but results in a layer of corroded metal underlying the surface and not having any strength. Corrosion medium travels along the grain boundaries affecting some of the constituents and leaving others intact, or depositing on them the products of the reaction, as in the case of pure Ni in hot sulphurous gases. Intercrystalline corrosion takes place by the action of some reagents on the grain boundaries depriving the metal of all its strength without affecting its weight. Strains and specific reagents are indispensable to produce it. Without any change in dimensions, loss of weight or properties determinable by tensile testing a metal can become very brittle, often only temporarily. This phenomenon is usually associated with the generation of nascent hydrogen on the surface of the metal. A comprehensive investigation of corrosion problems must take care of the usually accepted factors: chemical composition of the corroding media with a particular attention to its impurities; hydrogen ion concentration and its variations with the time; the surrounding atmosphere with particular attention to the amount of dissolved oxygen; temperature and pressure, agitation and viscosity of the liquid; electrical conductivity of the corroding media; the illumination of the specimens; chemical composition and impurities of the specimens; their structure involving, therefore, the history of the metal; internal stresses; surface; radii of curvature and the orientation in regard to the motion of corroding liquid; the ratio between the surface of specimens and the volume of liquid; electrical potential of the specimen; metals and alloys in contact with it; stresses applied during testing. One has to add to this list: lack of homogeneity in any metallic object; difference in concentration of the reagent; the influence of the dissolved oxygen; temperature fluctuations; chemical composition of the constituents of an alloy; irregularities in the structure; non-uniformity of strains, thermal gradient; differences in the state of the surface, etc. The matter is further complicated at the present by the lack of any general relation between these factors and corrosion. Many examples are given for demonstration of opposite effects produced by any of these factors under different conditions.

Determination of corrosion by measuring e. m. f. generated, electrolytic potentials or electrochemical pressure is not suitable. These factors vary too much and too fast from spot to spot while the oxidic film formed introduces an uncontrollable variable. The measurement of heat of solution can be applied to strong reagents and fast solution, but in true corrosion the heat generated cannot be estimated. Weighing after corrosion is very unsatisfactory. It can be applied only when no coating is formed and no penetration takes place. It never gives any information regarding type of corrosion, cannot be used for an uninterrupted study and requires a reasonably strong attack. In case of non-conducting media it can be substituted by determination of some of its functions, like conductivity. Absolutely arbitrary and involving a strong human factor determination of the changes in appearance by visual examination seems to be principally suitable for slight corrosions. Microscopical examination of the previously polished specimens furnishes zero point of corrosion and helps the study of attackability of the constituents of an alloy. Photoelectric method both sensitive and accurate is valuable for slight corrosions. Elongation and reduction of area are good indicators of localized and fissure corrosion. Notched impact test does not reflect surface conditions. Impact test on solid bars is good for localized and fissure corrosion. The measurement of the gas evolved is accurate, continuous and does not interfere with the tests. It cannot be used for slight corrosions when gases remain dissolved, occluded or form in too small a quantity. Weighing the precipitate separated from the sample can seldom be used. The changes in chemical composition and properties of the corroding liquid show very slight losses of metal or determine the factor of solubility of different constituents of an alloy but involve the interruption of tests. Nine types of methods for determination of corrodibility are given. The broadest summation of the present viewpoint: All heterogeneities in corrosion factors lead to an increased effect due to electrolytic action; all industrial alloys are unstable in the presence of oxygen and are protected only by the formation of an oxidic film; if a metal is corroded under a certain set of conditions the effect will continue indefinitely if nothing is changed; chemical resistance (of noble metals) and the passivity of some alloys can be transmitted to their solid solutions to a certain extent, provided their concentration is sufficient; the corrodibility of solid solutions changes suddenly as a function of the concentration of their constituents. A practical application of these principles to the corrosion of stainless steels is given as an illustration. The paper being a summary of the present conception of the mechanism of corrosion yields to abstracting only with difficulty. JDG

Corrosion of Metals as Affected by Stress, Time and Number of Cycles. D. J. McAdam, Jr. *Technical Publication* No. 175, *American Institute Mining & Metallurgical Engineers*, Feb. 1929, 57 pages.

Metals and alloys which corrode readily have their rates of corrosion increased by steady tensile stress. If the stress is released from time to time, that is, if the stress is intermittent, the rate of corrosion is still more markedly increased, Cycle stress of low frequency, for example, 1 cycle per day, accelerated corrosion pitting materially over that produced by stressless corrosion. Increased time, increased stress-cycle frequency (at least up to the maximum speed, 1450 r. p. m. used), any 2 of the 3 remaining constants, accelerates corrosion. The relationship between corrosion-stress and either time or number of cycles necessary to cause constant damage is exponential. The damage due to corrosion is evaluated by determining the fatigue limit of the material in air after it has had preliminary corrosion under repeated stress. The fatigue limit falls as the corrosive attack increases, unless strengthening by understressing occurs at the bottoms of the corrosion notches. The stress imposed during corrosion and the stresses of the final fatigue test are only nominal since the actual endurance limit of the material does not change, the real change being in the stress concentration set up in the notches caused by corrosion. More than 70 graphs or families of graphs are utilized to show the interrelation of the variables studied with the fatigue limit of 7 steels, 2 of which were tested in 2 or more conditions of heat treatment, after stress-corrosion in (1) fresh (carbonate) water, (2) in Severn River water, which has $^1/_3$ the salinity of sea water. No data are given on specially corrosion-resistant steels or on non-ferrous alloys. The materials used were ingot iron; 0.25 and 1.10% carbon; 0.50% carbon, 3% nickel, $1^1/_2$ % silicon; 0.03% carbon, $3^1/_2$% nickel; 0.03% carbon, $1^1/_2$% nickel, $^3/_4$% chromium; and 0.45% carbon, 2% nickel, 1% chromium steels. The endurance limits of the uncorroded materials ran from 24,000 to 108,000 lb/in.^{2}. The type of corrosion encountered was by pitting, no materials tending to corrode in an intercrystalline manner were used. Work on corrosion-resistant steels and non-ferrous alloys is in progress.—*From abstracts prepared by the A.S.T.M. Committee on Fatigue of Metals.*

Corrosion-resisting Steel for Laboratory Use. G. A. Stokes. *Analyst* Sept. 1929, Vol. 54, page 538.

Stainless steel capsules are stated to be superior to either aluminum or nickel in determination of total solids in milk, vinegar, etc.—*Abstract Bulletin Kodak Research Laboratories.*

Report on Bureau of Standards Soil Corrosion Investigation. K. H. Logan. *Preprint, American Petroleum Institute Meeting*, Dec. 5, 1929, 2 pages.

Brief résumé of the status of the work. HWG

Preliminary Results of Comparative Corrosion Tests with Painted Sheets with or without Copper. (Vorläufige Ergebnisse vergleichender Rostungsversuche mit gestrichenen, gekupferten und ungekupferten Blechen.) H. T. van Royen, H. Kornfeld & A. Schwarz. *Stahl und Eisen*, Oct. 31, 1929, Vol. 49, pages 1588–1589.

Painted sheets, containing copper, subjected for 2 years to the atmosphere were corroded much less than those without copper. GN

Corrosion of Metals as an Electrochemical Problem. A. Thiel. *Zeitschrift für Elektrochemie*, Sept. 1927, Vol. 33, pages 370–388.

Specimens of zinc alone and in combination with other metals were immersed in acid solutions and the evolution of hydrogen measured. It was found that hydrogen was liberated by a couple, rather than by zinc alone, but that the amount of hydrogen liberated by the zinc of the couple was less than that liberated by the zinc when alone. This difference between the hydrogen evolution from zinc alone and in combination was termed the "difference effect" and was found to be proportional to the current of flowing. With increased solution of zinc when coupled, the "difference effect" approaches as a limit the product of the current flowing and the proportionality constant, K, between the difference in gas evolution and current flowing. Further the proportionality constant is independent of the metal coupled to the zinc. The experiments which were repeated with aluminum gave similar results. Experiments on very pure zinc showed only slight attack except in cases where the metal was scratched. Graphite had a higher hydrogen overvoltage than pure iron; therefore, the accelerated corrosion of iron containing graphite is accounted for by the breaking up of the surface and to strains present in the metal.—*Abstract Bulletin Kodak Research Laboratories.*

Corrosion of Open-Valley Flashings. K. Hilding Beij. *Bureau of Standards Journal of Research*, Dec. 1929, Vol. 3, pages 937–952.

In recent years some trouble has been caused by corrosion of copper flashings, particularly of open-valley flashings on buildings with shingle roofs. Sixteen-ounce copper may be perforated in 15 to 20 years under severe conditions of service. Failures have been found in a few localities only. They seem to be more frequent in New York City and its environs than elsewhere in the Eastern and Central States. One case from Washington, D. C., is significant for here the corrosion occurred where one sheet of copper overlapped another. The corrosion, for convenience called line corrosion, results in a narrow line of holes or cracks immediately under the edge of the overlying roofing. It appears to be an accelerated attack due to differential aeration of the water retained by capillarity between the roofing and the flashing after a rainfall. This water is shielded from the air except along the edge of the roofing where it is freely exposed. Accelerated corrosion tests showed that a solution containing both sulphur dioxide and sodium chloride produced rapid line corrosion. Solutions of either alone produced no visible line corrosion in the same length of time. This result suggests that under ordinary conditions line corrosion will be found only in cities near the seacoast. The rate of corrosion depends in large measure on the roofing material. A porous, absorbent roofing, such as wood shingles, holds more water in contact with the flashing after a rainfall and dries out more slowly than a relatively impervious material like slate. Hence, more rapid corrosion takes place. The laboratory tests indicate that a simple and inexpensive modification in construction will eliminate troubles due to line corrosion. This modification consists of the insertion of a smoothly finished hardwood strip between the roofing and the flashing. The strip should be placed about an inch back of the edge of the roofing and nailed firmly and tightly to the flashing. In the accelerated tests, specimens made in this way were unaffected by more than three times the test exposure which caused line corrosion failure of specimens without the strip. It is reasonable to believe that a similar difference will be found under service conditions. If so, then no appreciable line corrosion would occur with the modified construction in 50 years or more even under conditions as severe as those in New York City and its environs.

Nickel and Nickel Alloys Offer Diverse Corrosion Resistance. R. J. McKay. *Chemical & Metallurgical Engineering*, Sept. 1929, Vol. 36, pages 546–548.

Pure Ni is fairly resistant to acids, alkalies and salts, and is not toxic in contact with foods. Alloys with proper quantities of copper or chromium are more resistant than the pure metal. Alloys containing 80–85% Ni and balance Cr are widely used for their resistance to oxidation and sulphurization at high temperatures and to some extent for resistance to HNO_3 and other oxidizing acids. Ni-Cr alloys of the Monel metal types are resistant to acids and alkalis. Alloys containing 60, 35, 22, 18 and 8% Ni, 10–20% Cr, and balance Fe retain high mechanical properties and resistance to oxidation up to high temperatures, and become completely passive to attack by oxidizing agents and some acids. Other alloys such as 35–45% Ni and balance principally copper, nickel silvers, etc. are resistant to mild forms of corrosion. Contains some observations on the determination and expression of corrosion resistance of Ni alloys. MS

STRUCTURE OF METALS AND ALLOYS

Metallography and Macrography

Changes in Iron at the Critical Point. B. A. Rodgers. *Heat Treating & Forging*, Oct. 1929, Vol. 15, pages 1307–1309, 1380.

Bibliography of 10 references. Paper read before the American Institute of Mining & Metallurgical Engineers. See Metals & Alloys, July 1929, Vol. 1, page 24. MS

Methods of Research in Metallography. G. Masing. *Heat Treating & Forging*, Oct. 1929, Vol. 15, pages 1310–1314, 1323.

Paper read before the Institute of Metals. See Metals & Alloys, Jan. 1930, Vol. 1, page 341. MS

Observations on the Iron–Nitrogen System. S. Epstein, H. C. Cross, E. C. Groesbeck & I. J. Wymore. *Bureau of Standards Journal of Research*, Dec. 1929, Vol. 3, pages 1005–1027.

By means of thermal analyses, microscopic examinations, and X-ray analyses of nitrided electrolytic iron specimens a study has been made of the iron–nitrogen system. From the data obtained and with the diagrams of Sawyer and Fry as a basis, a modified iron-nitrogen constitution diagram has been tentatively drawn. The upper temperature horizontal noted by Sawyer was also observed, but this has been ascribed to a peritectoid instead of a eutectoid transformation. Three nitrided layers were observed, whereas Fry noted only two. The 3 layers have been designated as Fe_2N, Fe_4N and Fe_6N. Observations on several specimens of aluminum molybdenum nitriding steel are also described.

Photomicrography with Simple Means Using Modern Developments in Apparatus. M. Wolff. *Photographische Korrespondenz*, Jan. 1929, Vol. 65, pages 18–21; Feb. 1929, pages 51–54; March 1929, pages 81–87; April 1929, pages 114–117.

Simple, general directions for the amateur in photomicrography are given. The merits of various German microscopes are discussed. Illustrations of the use of the Busch, Leitz, Zeiss and Reichert photomicrographic cameras and accessory devices are given.—*Abstract Bulletin Kodak Research Laboratories.*

Identification of Segregations of Sulphur and Phosphorus by Means of the Test on Sulphur According to F. Fiegl. (Die Erkennung von Schwefelseigerungen neben Phosphorseigerungen mit Hilfe des Sulfidnachweises nach F. Feigl.) M. Niessner. *Archiv für das Eisenhüttenwesen*, Aug. 1929, Vol. 3, pages 157–161; *Stahl und Eisen*, Sept. 19, 1929, Vol. 49, pages 1378–1379.

F. Feigl applies an extremely sensitive reaction on sulphur when sulphur and phosphorus are present at the same time. Soluble as well as non-soluble sulphides react immediately when sprayed with a solution of iodine in NaN_3. Neissner carefully investigated Feigl's method and states that it is an easy and simple means of distinguishing between sulphides and phosphides on prints of segregations as originally proposed by E. Heyn, O. Bauer and Baumann. GN

Structure and X-Ray Analysis

Progressive Coalescence of Pearlite. J. H. Whiteley. *Heat Treating & Forging*, Oct. 1929, Vol. 15, pages 1320–1323.

Paper read before Iron & Steel Institute, Sept. 1929 entitled "The Coalescence of Pearlite." See Metals & Alloys, Jan. 1930, Vol. 1, page 340.

Some Results of Crystallographic Studies with X-Rays. (Sur quelques resultats d'essais cristallographique par rayons X.) Albert Roux & Jean Cournot. *Revue de Metallurgie*, Dec. 1929, Vol. 26, pages 655–661.

A series of experiments for determination of the structure of simultaneously electrodeposited metals by means of X-rays. Ag–Cd, Sn–Cd, Ni–Cd and Cu–Zn systems were studied. Electrolytic deposits but seldom consist of superimposed layers of 2 metals. Usually they are formed of alloys specified by their equilibrium diagram. JDG

X-Ray Investigations of Fractures. (Röntgenuntersuchungen an Brüchen.) F. Regler. *Paper read before Deutscher und Oesterreichischer Verband für Materialprüfung*, Vienna, Oct. 8–11, 1929.

The importance of X-ray examination in testing materials is emphasized. GN

Investigations of Materials by Means of X-Rays. (Untersuchung der Werkstoffe mit Röntgenstrahlen.) R. Glockler. *Paper read before Deutscher und Oesterreichischer Verband für Materialprüfung*, Vienna, Oct. 8–11, 1929.

The general characteristics of X-rays, the methods and principles of application, X-ray tubes and some examples of practical X-ray investigations are outlined. GN

Quantitative X-Ray Analysis. (Quantitative Röntgenanalyse.) H. Stintzing. *Paper read before Deutscher und Oesterreichischer Verband für Materialprüfung*, Vienna, Oct. 8–11, 1929.

The advantages of the X-ray emission method for quantitative chemical analysis are considered. Simplicity of spectrum and accuracy are the main features. The method was improved by Stintzing and sources of errors were eliminated. GN

Studies on Metal Structure by Means of X-Rays. (Aufbau der Metalle im Röntgenbild.) F. Wever. *Paper read before Deutscher und Oesterreichischer Verband für Materialprüfung*, Vienna, Oct. 8–11, 1929.

X-rays are the only possibility to reveal the atomic structure of metals and to build up an atomic metal science. Investigations of Westgren and Phragmén show that the generation of certain structures of copper-silver alloys is bound to the observation of a determined quantitative relation between atoms and electrons. The possibilities for the development of new iron alloys by means of the structure analysis are outlined. GN

Deformation of Metallic Materials as Revealed by X-Rays. (Verformung metallischer Werkstoffe im Röntgenbild.) Dr.-Ing. Sachs. *Paper read before Deutscher und Oesterreichischer Verband für Materialprüfung*, Vienna, Oct. 8–11, 1929.

The far-reaching possibilities in applying X-rays to studies of the deformation of metals are considered. Investigations on cold drawn wire, rolled sheets, effects of re-crystallization, interior stresses in metals are referred to. GN

Re-crystallization of Electrolytic Iron. (Rekristallisation von Elektrolyteisen.) F. Halla. *Deutscher und Oesterreichischer Verband für Materialprüfung*, Vienna, Oct. 8–11, 1929; *Stahl und Eisen*, Dec. 12, 1929, Vol. 49, pages 1799–1800.

The changes of structure and physical properties in annealing electrolytic iron are investigated. Thin sheets (0.28–0.30 mm.) have not yet completely released absorbed hydrogen at 1000° C. X-ray investigations of sheets with variable hydrogen content from 0.0039 to 0.021% show no change of the lattice parameter with increasing hydrogen content. GN

PHYSICAL, MECHANICAL AND MAGNETIC TESTING

Heat Treatment and Mechanical Properties of Some Copper-Zinc and Copper-Tin Alloys Containing Nickel and Silicon. W. C. Ellis & E. E. Schumacher. *Technical Publication* No. 188, *American Institute Mining & Metallurgical Engineers*, March 1929, 17 pages.

Ellis and Schumacher describe brasses to which about $2^1/_3\%$ of nickel and $^2/_3\%$ of silicon have been added so as to make it possible, through the presence of nickel silicide (Ni_2Si), to harden the alloys by a heat treatment of the same type as that used on duralumin. Alloys, all with 3% of Ni_2Si, and with 10, 20 and 30% of zinc, balance copper, were tested. The proportional limit of the heat-treated alloys ran from 37,000 to 45,000 lb./in.^{2}, the tensile strength from 85,000 to 90,000 lb./in.^{2}, the elongation 14 to 28% in 2 in., the modulus of elasticity from 16,500,000 to 20,000,000 lb./in.^{2} The endurance limits (for 100 million cycles) were given as ranging from 13,000 to 16,000 lb./in.^{2}. Materials with as good or better endurance limits than ordinary spring brass, with a higher modulus of elasticity and with very much improved ductility are, therefore, available and offer promise for springs. The springs may be formed in the annealed condition and the desired hardness and strength obtained by heat treatment, rather than by cold working as is required in spring brass.—*From abstracts prepared by the A. S. T. M. Research Committee on Fatigue of Metals.*

A High-Speed Endurance Testing Machine for Leaf Springs. J. Bradley. *Engineering* (London), Jan. 11, 1929, pages 36–37.

A testing machine for testing a leaf of a flat spring under cycles of repeated or reversed stress is described. A speed of 1000 cycles per minute can be attained. The machine consists of a linkwork holding the specimen, and the magnitude of stress applied is measured by the deformation of 1 link. A 1 hp. motor is required to run the machine. The test specimen requires no preliminary machining and is subjected to a uniform bending moment over several inches of length. The stress is independent of the speed of operation, within 0.5% from a speed of 1000 r. p. m. down to static conditions. Results are quoted showing a good check between tests on this machine and tests of the same material on a rotating-beam machine.—*From abstracts prepared by the A. S. T. M. Committee on Fatigue of Metals.*

Endurance Tests. (Dauerbiegeversuche.) P. Ludwik. *Paper read before Deutscher und Oesterreichischer Verband für die Materialprüfung*, Vienna, Oct. 8–11, 1929; *Zeitschrift Vereins deutscher Ingenieure*, Dec. 1929, Vol. 73, pages 1801–1810.

The author discusses the theoretical basis of endurance tests, considers the relations between fatigue strength and other physical properties and reports on a large number of tests which were carried on recently by the Technische Versuchsanstalt of the Technische Hochschule in Vienna as alternating bending tests with reinforced concrete bars, tests with a large variety of steels, cast iron, light metals, copper, zinc, brass in different machines (C. Schenk, A. I. Amsler tip machine). GN

The Fatigue of Rolled Aluminum Alloys. G. Sachs. *Zeitschrift für Metallkunde*, Jan. 1929, pages 27–29.

This paper is a survey of the work done on the above subject, with no tests by the author. According to Wagner, heat-treated aluminum alloys show about 20% higher fatigue strength than those which have been annealed; while the corresponding difference in tensile strength is nearly 100%. The ratio of the endurance limit to the ultimate strength of heat-treated aluminum alloys is therefore low, in some cases as low as 0.2. In general, working seems to decrease rather than increase the fatigue strength of heat-treated aluminum alloys. The unfavorable data revealed by fatigue tests would seem to contradict the successful use of heat-treated aluminum alloys in airplane construction. The author points out the actual conditions are not duplicated in fatigue testing, inasmuch as in general the actual loading is more or less uniform.—*From abstracts prepared by the A. S. T. M. Committee on Fatigue of Metals.*

Discussion of Wollmar's Paper on "Tests of Drill Steel." L. Nordenfelt. *Mining & Metallurgy*, Feb. 1929, Vol. 10, pages 84–87.

Alleges that freedom from inclusions in the steel at the bore of the hollow drill steel described by Wollmar makes it resistant to corrosion. Hollow drills lined with either Armco or rustless iron, tried out on a large scale in South Africa have been a total failure. In answer to Armstrong's claim that Wollmar's comment on unsatisfactory service of drill steel with a rustless iron tube as core must refer to poorly welded material, Nordenfelt shows a micrograph of such steel in which the welding appears complete, but alleges that segregation of the drill steel occurs near the rustless tube and that these segregations have a detrimental influence. Both discussions are polemical. All 3 writers agree, however, that roughness or corrosion of the bore favors fatigue failure.—*From abstracts prepared by the A. S. T. M. Committee on Fatigue of Metals.*

Fractures of Steel and the Meaning of the Transition Field of Notch Toughness. (Die Brucharten des Stahles und die Bedeutung des Uebergangsgebietes der Kerbzähigkeit.) F. Fettweiss. *Stahl und Eisen*, Nov. 7, 1929, Vol. 49, pages 1621–1628.

Report No. 157 of the Materials Committee of the Verein deutscher Eisenhüttenleute. Includes discussion. In covering the literature on the interesting phenomenon that, within a certain range, the notch toughness bears no simple relationship to such variables as temperature, width of sample, shape of fracture, etc., the author gives new explanations. He states that the zone of transition of the notch toughness from low to high values is always subjected to the same rules whatever the appearance of the transition field. When this zone can be identified in examining the notch toughness of a steel in relation to the width of the test samples then it should also be observed in relation to the temperature. The change of fracture from granular to fibrous is always unsteady. The fibrous fracture bears no relation to a certain crystal plane but the granular fracture occurs along certain planes. The shape of fracture depends upon the state of stresses within the breaking sample. GN

A New Stress Limit and Its Relation to Fatigue Strength. (Eine neue Spannungsgrenze und ihre Beziehung zur Dauerfestigkeit.) Dr.-Ing. Sachs. *Paper read before Deutscher und Oesterreichischer Verband für Materialprüfung*, Vienna, Oct. 8–11, 1929.

The Bauschinger effect depends upon the preceding deformation of a material and increases with the deformation to a certain limit. Stresses which cause slight deformations have no influence on the Bauschinger effect of a certain group of non-ferrous metals. The Bauschinger effect originates at stresses above elastic limit and yield point. However iron and steel show the Bauschinger effect, as soon as permanent deformations can be observed with fine extensometers. It is confirmed that permanent deformations in steel can occur below the yield point. Elastic limit and yield point are less important for the phenomenon of fatigue. GN

Some Aspects of Corrosion Fatigue. T. S. Fuller. *Technical Publication* No. 172, *American Institute Mining & Metallurgical Engineers*, Feb. 1929, 8 pages.

To study the effect of hydrogen, experiments were made with a 0.35% carbon, 3.5% nickel steel quenched and tempered to give a tensile strength of 110,000 lb./in.^{2} and a yield point of 80,000 lb./in.^{2}. Rotating beam tests, made with a correctly designed Moore and Jasper type bar, but run all at a single nominal stress of 90,000 lb./in.^{2}, that is, above the yield point of the material, were used as a criterion of the damage resulting from various treatments. Comparison was made on the basis of cycles to fracture at that stress, and it is admitted by the author that this tells nothing about the true endurance limit, and that the work only gives a rough preliminary indication. The data obtained were:

Treatment	No. of Specimens	Life, Cycles Maximum	Minimum	Average
Uncorroded	4	141,000	105,000	120,000
1 hr. in 10% H_2SO_4	2	66,000	62,000	64,000
1 hr. in 10% H_2SO_4, heated	2	74,000	77,000	76,000
Cathode in 5% NaOH, 24 hrs.	1	78,000	.....	80,000
Cathode in 5% NaOH, 48 hrs.	1	82,000	.....	
1 month in steam and air	2	35,000	27,000	31,000
1 week in running tap water	2	51,000	36,000	43,000
1 week in running tap water, heated	2	42,000	38,000	40,000
Hot galvanized, 1 week in running tap water	2	34,000	30,000	32,000
Tin dipped, 1 week in running tap water	2	179,000	141,000	160,000

Since the specimens made cathode in NaOH showed no pitting, the reduction in life is assumed to be due to absorbed hydrogen and the slightly better life of the acid pickled specimens after heating to 130° C. for 4 hrs. is ascribed to the removal of hydrogen. The drop in cycles to break the pickled specimens from which hydrogen was removed is, of course, due to pitting. Pitting caused by exposure to steam for a month or to running tap water for a week produces much more damage than the more even attack resulting from pickling 1 hour in 10% H_2SO_4. The most interesting point in Fuller's work relates to the effect of hot-galvanized and hot-tinned coatings. The zinc-coated specimens, although not pitted by tap water, showed shorter lives than uncoated specimens in tap water, that were badly corroded. The galvanized specimens developed cracks in the brittle $FeZn_3$ layer which extended themselves into the metal below. The tin-coated specimens, on the other hand, after a week in tap water, gave lives as good as, or better than, uncoated and uncorroded specimens.—*From abstracts prepared by the A.S.T.M. Committee on Fatigue of Metals.*

The Behavior of a Single Crystal of Zinc Subjected to Alternating Torsional Stresses. H. J. Gough & H. L. Cox. *Proceedings, Royal Society of London*, March 6, 1929, Vol. 123, pages 143–167.

Previous reports have described experiments on single crystals of aluminum (face-centered cubic) and iron (body-centered cubic). The present paper describes an experiment on a single crystal of zinc, a metal crystallizing in the hexagonal (close-packed) lattice. As in the previous tests of aluminum and of iron, the tests were carried out with great elaborateness of detail and the relation between the various planes of the space lattice and the observed direction of slip and of fracture were carefully studied. The general conclusions regarding the action of a zinc crystal under alternating torsional stress were as follows: deformation, by slip, of a zinc crystal is controlled purely by resolved shear stress considerations and occurs along the most highly stressed primitive direction contained by the basal plane. The "visible slip limit" (probably of the present specimen only) was clearly defined at a range of resolved shear stress of ± 1 ton/in.^{2} (± 2240 lb./in.^{2}), while the limiting range (fatigue range) of reversed shear stresses, in the case of the present crystal has a value intermediate between ±1.0 and ±1.3 ton/in.^{2} (±2240 and ±2910 lb./in.^{2}) in terms of resolved shear stress. Fracture resulted in three general directions: (1) Parallel to the traces of the original basal plane; (2) parallel to the traces of the twinned basal plane within the twinned structure; and (3) along the edges of the twins. The latter direction may be due either to the twin boundary being a place of weakness, or to the fact that, in the present specimen, these boundaries were exposed to a maximum range of normal stress, or to a combination of these conditions. Prismatic planes are neither slip nor cleavage planes, and it appears very probable that what have previously (by other investigators) been interpreted as cleavages of this type, have been cleavages or fractures along twinned basal planes.—*From Abstracts by the A.S.T.M. Research Committee on Fatigue of Metals.*

Testing of Deep Drawing Sheet. (Die Prüfung von Tiefziehblech.) M. Schmidt. *Archiv für das Eisenhüttenwesen*, Sept. 1929, Vol. 3, pages 213–222; *Stahl und Eisen*, Nov. 21, 1929, Vol. 49, pages 1695–1696; *Iron & Coal Trades Review*, Dec. 1929, Vol. 119, page 913; *Metal Stampings*, Feb. 1930, Vol. 3, pages 117–118.

The topic of the investigation is the examination of the physical properties of sheets for deep drawing. The different test methods are considered and compared, as for instance, the Erichson method with the Amsler indentation method. The results of practical drawing tests are in sufficient accordance with the limit of drawing as determined by tensile tests. The agreement with the Erichson test is less favorable. Cold rolled and recrystallized sheets show a minimum drawing limit if the material was coarse grained as a result of critical deformation and subsequent annealing. To estimate the suitability of sheets for deep drawing an effort was made to determine if high reductions can be made in a single draw or if several draws can be produced without annealing between the draws. The author calls this property" cold plasticity." GN, RHP & MS

The Strength and Toughness of Ferrous Metals. R. A. Bull. *Research Group News*, Jan. 1929, Vol. 5, pages 205–219.

Discusses in popular fashion the significance of physical properties of metals and the meaning of mechanical tests, among them being the fatigue test. It is pointed out that there has been no standardization of apparatus for making fatigue tests. The deleterious effect of notches, sharp corners and poor fillets on endurance properties is cited as an argument for better design and machining methods to produce finished parts without such defects.—*From abstracts prepared by the A. S. T. M. Committee on Fatigue of Metals.*

Physical Properties (Including Endurance) of Alclad sheet. (Festigkeitsprüfung von Alclad-Blechen.) K. Matthaes. *Luftfahrtforschung*, May 29, 1929, Vol. 3, pages 153–160. Abstracted in *Zeitschrift für Metallkunde*, Nov. 1929, Vol. 21, pages 394–395.

Tensile properties of heat-treated Alclad (17ST) were found to be practically identical with those of duralumin (681B 1/3). The "elastic limits" or stresses for various percentage extensions under load were compared.

	Stress lbs./in.^{2}	
% Extension	Alclad	Duralumin
0.001	12000	20500
0.003	14500	28500
0.02	35000	34500
0.2	39000	41000

The S—N curve for 0.0625 in. Alclad sheet in a repeated bending endurance test is plotted as showing a sharp break at 14000 lbs./ in.^{2} occurring at about 1 million cycles. Only one test was carried beyond 2 million cycles, a point being shown on the plot at about 15 million. The apparently horizontal branch of the curve is, then, determined by only one point. Specimens tested at high stresses showed roughening of the aluminum surface but fatigue cracks other than the break itself, did not develop in the aluminum coating, nor did the coating separate from the base. The endurance testing machine used by the V. D. L. for thin sheet metal is illustrated. See also Metals & Alloys, Sept. 1929, page 122. HWG

Telephone Apparatus Springs. J. B. Townsend. *Transactions American Society Mechanical Engineers, Applied Mechanics Division*, Jan.-Apr. 1929, pages 81–83.

The requirements for telephone springs made from sheet metal are discussed. Modulus of elasticity, porportional limit, resistance to creep, ability to be soldered, resistance to corrosion, wear resistance, freedom from arcing when used as an electrical contact, and endurance limit are important factors. Endurance plots are given from tests usually carried beyond 200 million cycles before the semilogarithmic plot becomes flat. The specimen is tapered in the breaking section, and tested in repeated bending. The specimen is shown in detail but the endurance machine is not described. The tests are made at 700 cycles per minute. Results on No. 24 gage sheet follow:

	% Copper	% Zinc	% Nickel	% Tin	% Phosphorus	Numbers hard
Brass	66	34	..	..	..	4 10
Nickel Brass	55	27	18	..	..	4 10
Phosphor Bronze	Bal.	..	..	8	0.15	10

	Rockwell Hardness "B" scale	Tensile Strength lb./in.^{2}	Endurance Limit lb./in.^{2}
Brass	75–83	68,000–78,000	14,000
	86–90	89,500–98,500	13,000
Nickel Brass	.....	....	18,000
	77–82	111,000–123,000	22,000
Phosphor Bronze	78–83	109,500–122,000	25,000

From abstracts by the A. S. T. M. Research Committee on Fatigue of Metals.

Elastic and Inelastic Behavior in Spring Materials. M. F. Sayre. *Mechanical Engineering*, Dec. 1929, pages 915–916; *Metal Stampings*, Jan. 1930, Vol. 3, pages 47–48.

Progress Report No. 5 of the American Society of Mechanical Engineers, Special Research Committee on Mechanical Springs. Covering the results of investigations since the preceding report. Detailed description of the work done by the author. GN & MS

A New Special Testing Method for Cast Iron. (Ein Neues Sonderprüfverfahren für Gusseisen.) *Giesserei-Zeitung*, Nov. 1, 1929, pages 620–621.

Description of a new testing machine for cast iron, built by Mohr & Federhoff, Mannheim, Germany, which is especially for making shearing tests, according to a proposal by Rudeloff and Sipp. GN

Test Methods for Cast Iron. (Les Methodes d'Essai de la Fonte.) A. le Thomas & R. Bois. *Revue de Fonderie Moderne*, Sept. 25, 1929, pages 444–461.

Summarizing report and critical opinion of all applied methods and machines for testing the properties and qualities of cast iron. GN

Report of Tests on 1350 lb. W. S. P. Piping Materials. *Inco*, 1929, Vol. 9, No. 3, pages 15, 25–27.

The tests described in this article show the behavior of various piping materials in assembly when subjected to steam pressures of from 1200 – 1500 lbs. at effective and efficient operating temperatures. These tests determine the merits of individual items of piping equipment and give data in regard to a complete assembly of typical equipment under actual working conditions. The complete report in great detail may be obtained from the National Valve & Mfg., Co. Pgh., Pa. MLM

Testing Welds with Stethoscope. *Oxy-Acetylene Tips*, Jan. 1930, Vol. 8, pages 127–128.

Stethoscope testing of welds is non-destructive and can be applied to plate, pipe joints or structural steel joints with equal facility. Procedure in testing is given. MLM

The Relative Safety of Mild and High-Tensile Alloyed Steels Under Alternating and Pulsating Stresses. B. Parker Haigh. *Chemistry & Industry*, Jan. 11, 1929, Vol. 48, pages 23–30.

This paper gives a general discussion of the stress-cycles (or S-N) diagram and also a quite detailed discussion of the Haigh magnetic machine for producing cycles of stress in direct tension and compression. There is given a comparison between fatigue strength and tensile strength of various metals. The old idea that the tensile elastic range, if measured with due accuracy, would correspond with the limiting fatigue range has been abandoned.—*From abstracts prepared by the A S. T. M. Committee on Fatigue of Metals.*

Formation of Fatigue Cracks and the Relation between Alternating Bending Strength and Static Tensile Properties. (Ueber die Ausbilding von Ermüdungsrissen und die Beziehung der Dauerbiegefestigkeit zu den statischen Festigkeitswerten.) W. Herold. *Paper read before Deutscher und Oesterreichischer Verband für Materialprüfung*, Vienna, Oct. 8–11, 1929.

The influence of notch effects, of small surface defects or of internal defects, as for instance inclusions of slags or poorly welded blow holes or also that of a coarse grain decrease of the fatigue limit are dealt with. As regards the relationship between alternating bending strength and tensile properties, it is pointed out that alternating bending strength generally increases with the tensile strength but endurance strength increases slower than compression strength. Alloy steels have a higher fatigue limit than plain carbon steels. GN

Machines and Apparatus for Fatigue Tests. (Maschinen und Vorrichtungen für Dauerprüfungen.) W. Deutsch. *Paper read before Deutscher und Oesterreichischer Verband für Materialprüfung*, Vienna, Oct. 8–11, 1929.

The paper gives a general outline of machines, as applied to fatigue testing. GN

Fatigue Strength and Construction. (Dauerfestigkeit und Konstruktion.) O. Föppl & G. von Heydekampff. *Paper read before Deutscher and Oesterreichischer Verband für die Materialprüfung*, Vienna, Oct. 8–11, 1929.

In reference to the investigations of the Wöhler Institute Braunschweig, the viewpoints of the fitness of construction materials are considered. The importance of a high polish after grinding to improve the fatigue qualities is emphasized. Fatigue limit can be raised 10–20% by pressing the surface of materials in rolls. GN

A New Test Method for Sheets. (Ein neues Prüfverfahren für Feinbleche.) E. Siebel & A. Pomp. *Mitteilungen Kaiser Wilhelm Institut für Eisenforschung*, 1929, Vol. 11, No. 18, (Report 136), pages 287–291; *Stahl und Eisen*, Dec. 26, 1929, Vol. 49, pages 1866–1868.

The new method was developed as the conditions of power and deformation in the usually applied Erichson method are not definite. The new method eliminates this disadvantage. The apparatus is described, the theoretical principles of the method are outlined and the results of tests with various materials are given. GN

Hardness Tests of Chilled Castings. (Die Prüfung der Härte von Schalenhartguss.) O. Kenne. *Krupp'sche Monatshefte*, Dec. 1929, pages 200–203.

Numerous measurements with various Scleroscope hardness testers give various readings with the same test piece. Also one and the same instrument gives divergent readings, which decrease with very hard material. A method is proposed for checking scleroscopes. GN

Fatigue Cracks and Fatigue Strength. (Dauerbrüche und Dauerfestigkeit Erfahrungen und Versuchsergebnisse aus dem Reichsbahnbetrieb.) Dr.-Ing. Kühnel. *Paper read before Deutscher und Oesterreichischer Verband für Materialprüfung*, Vienna, Oct. 8–11, 1929.

The author deals with fatigue in 3 groups, fatigue cracks due to interior defects, to surface defects and those which cannot be traced back to a certain failure in the material. Tests in 3 different types of machines (Schenk, Amsler, Krupp) were carried on with low and medium carbon steel, structural steel, spring steel and cast iron. The results were reported. GN

Fatigue in Steels for Shafts. (Ermüdungseigenschaften von Kurbelwellenstahl.) Dr.-Ing. Matthaes. *Paper read before Deutscher und Oesterreichischer Verband für Materialprüfung*, Vienna, Oct. 8–11, 1929.

The report is a survey of investigations carried on by the "Deutsche Versuchsanstalt für Luftfahrt." Chemical composition, structure, grain size, content of nonmetallic inclusions, physical properties of generally applied steels for this purpose are given, as well as results on fatigue tests with shafts of 80–140 kg./mm.^{2} tensile strength. Different shaped shafts were examined. GN

Geometry, Wear and Testing of Safety Razor Blade Egdes. J. Ferdin & Kayser. *Engineer*, June 8, 1928, Vol. 145, pages 621–623; *Scientific American*, Oct. 1929, Vol. 141, pages 302–305.

Based on the examination and testing of several hundred blades purchased at retail. Microscopic examination at magnifications above 15 diameters, indicates that cutting edges may be grouped into four classes. Majority of blades are made from straight carbon steel containing 1.1–1.3% C. One of the makes was made from a high chromium steel. The microstructure of the plain carbon steel blades consists essentially of globular cementite embedded in a structureless matrix. The high chromium steel blades have a somewhat similar structure, but the matrix appears to be sorbitic. Blades giving unsatisfactory shaves showed that globules of cementite projected from the cutting edge. Chief destroying agent appears to be corrosion. Chromium steel blades wear by the falling out of the carbide particles. Microscopic control of production would prevent defective blades from leaving the works. Magnification of from 15 to 30 diameters shows a great deal. Discusses also work done in shaving, and the testing of the cutting durability of the blades. MS

A New Dead-Weight Testing Machine of 100,000 Pounds Capacity. L. B. Tuckerman, H. L. Whittemore & Serge N. Petrenko. *Bureau of Standards Journal of Research*, Feb. 1930, Vol. 4, pages 261–264.

The functions of the Bureau of Standards are outlined and the importance of calibrating testing machines is emphasized. The different methods of calibrating testing machines (A. S. T. M. specifications) are given, and the limitations of each are discussed. The development of the proving ring is mentioned, and the need for apparatus for applying, preferably by dead weights, forces which are known accurately is brought out. The dead-weight machine, capacity 100,000 pounds, which has been installed at the bureau is described and illustrated. Particular attention is given to the accuracy of the forces which can be applied by this machine and the precautions for maintaining the accuracy.

Fatigue and Corrosion-Fatigue of Spring Material. D. J. McAdam, Jr. *Transactions, American Society Mechanical Engineers, Applied Mechanics Division*, Jan.-Apr., 1929, pages 45–65

Includes discussion. Data are given on 44 compositions or heat treatments of steels and on 37 non-ferrous metals. Many of the data have been previously published, but some new data are included, and chief attention is paid to materials that might be used as springs.—*From abstracts prepared by the A. S. T. M. Committee on Fatigue of Metals.*

ELECTRO CHEMISTRY

Electroplating

Excess Sulphate Control in Chromium Plating Baths. Charles H. Proctor. *Metal Cleaning & Finishing*, Oct. 1929, Vol. 1, pages 507–510.

Difficulties were encountered in a plant because the solutions contained over 60 oz. of chromic acid per gal. and an excess of sulphate. To correct the problem, the chromic acid content was reduced to 33 oz. per gal. by removing half of the solution and diluting the remainder with clean, cold water. Soda ash was then added to neutralize the excess H_2SO_4. Results were obtained which were as good as when chromium plating was first started. MS

Electroplating and Electrometallurgical Methods. (Galvanische und elektrometallurgische Verfahren.) G. Eger. *Siemens Zeitschrift*, Nov. 1929, pages 761–765.

The article refers to electrolytic methods in general and to chromium and cadmium plating in particular. German and American chromium plating plants are described. Electrolytic methods for metal production are considered. GN

Some Chromium Plating Experiments. Chester M. Alter & Frank C. Mathers. *Metal Cleaning & Finishing*, Oct 1929, Vol. 1, pages 517–518, 531–532; *Metal Industry* (London), Dec. 6, 1929, Vol. 35, pages 545–546.

From paper read before American Electrochemical Society, Sept. 19–21, 1929. See Metals & Alloys, Jan. 1930, Vol. 1, page 342. MS

INDUSTRIAL USES AND APPLICATIONS

Building of Aircraft Is Specialized. John F. Hardecker. *Iron Trade Review*, Oct. 3, 1929, Vol. 85, pages 839–842, 852.

Rapid progress in airplane manufacture was made possible by the skill of the parts manufacturers. Among the specialties are the standard structural parts, mostly screw machine products, made of S.A.E. 2330 or 1025 steel. Cr-Mo seamless tubing, S.A.E. 4130X analysis, is of major significance. A wide variety of extruded duralumin shapes finds extensive application. Extra heavy alloy steel tubing is used for axles, etc. Floats are made of duralumin, monel metal, etc. The majority of engine parts are screw machine products made from materials including high-speed steel, Al bronze, etc. Bohnalite is finding application in the form of castings and extrusions. Engine cowls and propeller noses are spun from Al or duralumin. Fuel tanks are constructed of welded Al, although terne plate also is used. MS

Chamber Acid Depends Upon Lead. George O. Hiers. *Chemical & Metallurgical Engineering*, Sept. 1929, Vol. 36, pages 555–556.

Pb equipment is used extensively in sulphuric acid manufacture, use and handling, phosphoric acid manufacture, sulphonation and chlorination processes, explosives industries and hydrofluoric acid handling. Two varieties are used: chemical Pb, containing 0.04–0.08% Cu, 0.005–0.15% Ag and less than 0.005% Bi, and hard Pb, containing up to 12% Sb. Both are used in the forms of sheet and pipe. Because of the greater strength of hard Pb sheet, it is used extensively for electrolytic tanks. At 100° C. the strengths of the 2 varieties are almost the same, as the hard Pb is more fusible. Pb is being reinforced by stronger metals, such as steel. The metals are bonded together with a thin film of Sn or solder, or they are joined directly together with the aid of careful fluxing. Anodes consisting of 98.8% Pb, 1% Ag and 0.2% As, are used in producing 99.995% eletrolytic Zn. Pb is used for anodes and tank linings in Cr plating. MS

British and American Automotive Steel. Part IV. J. W. Urquhart. *Heat Treating & Forging*, Sept. 1929, Vol. 35, pages 1172–1175; *Blast Furnace & Steel Plant*, Oct. 1929, Vol. 17, pages 1517–1520.

Ni-Cr steels are superseding C-Mn-Cr steels for crankshafts. They have a high elastic limit, high resistance to Stanton blows, and maximum resistance to heat deterioration. The low critical temperature is of utmost importance in crankshaft and front axle manufacture. The depth of hardness in these steels is markedly superior to that of C steel, at a given quenching temperature. Parts made from Ni-Cr steels present some difficulty in the truing operation, and a special tool steel must be used. Fractures in crankshafts usually occur in those that have been machined from a solid slab of steel, and not in those that have been twisted from steel bar. Carbon steel springs were often too hard and fractured. Ford used a C-Mn-Cr steel and secured good results. High carbon steel springs are used satisfactorily at present, as advances in heat treating have made it possible to heat treat the steel so that free cementite (the crack initiating material) is not formed. Ni-Cr steels are now used for springs in high-grade European cars. The resilience of springs made from these steels depends upon the hardness remaining after tempering and the temperature attained at the moment of quenching. MS

Use of Alloy Steels in Steel Mill Equipment. E. R. Johnson & O. Bamberger. *Rolling Mill Journal*, Sept. 1929, Vol. 3, pages 403–404.

Abstract of paper presented at a meeting of the Iron and Steel Division of the American Society of Mechanical Engineers in Cleveland, Sept. 13, 1929. The Central Alloy Steel Co. is substituting various alloy steels for plain carbon steels for certain parts of rolling-mills and other steel mill equipment, where it is necessary to increase strength, ductility, toughness and resistance to wear, abrasion and corrosion. The alloy steels which have been developed include the elements nickel, chromium, molybdenum, vanadium, tungsten and copper, either singly or in combination. Gives specific illustrations of their use. MS

Magnesium and Its Alloys. W. G. Harvey. *American Machinist*, Oct. 10, 1929, page 624; *Metal Industry* (London), Dec. 27, 1929, Vol. 35, pages 615–617; *Heat Treating & Forging*, Oct. 1929, Vol. 15, pages 1317–1319.

Abstract of a paper presented at the meeting of the American Electrochemical Society, Sept. 19–21, 1929, at Pittsburgh. See Metals & Alloys, Feb. 1930, page 385. RHP

Physical Characteristics of Wire for Mining Ropes. A. T. Adam. *Rolling Mill Journal*, Nov. 1929, Vol. 3, pages 473–474.

Abstract of paper read before Iron & Steel Institute. See Metals & Alloys, Jan. 1930, Vol. 1, page 343. MS

Aluminum Conductors and Corona. Edgar Painton. *Electrician*, Jan. 31, 1930, Vol. 104, pages 137–138.

Aluminum is proving lighter, stronger and cheaper than hollow copper for cables. A steel-cored aluminum conductor is used on the Conowingo and Wallenpaupeck lines in Pennsylvania and on the Gatineau lines in Ontario. The voltage is 220,000. While the hollow copper conductor has a smoother surface and a slightly smaller diameter, it weighs 3.46 tons per mile compared with 2.41 tons for steel-cored aluminum conductors, and tensile strengths are 10.0 tons and 12.6 tons, respectively. When a large core section is necessary the aluminum should be in 2 or more layers stranded in opposite directions. WHB

Throwing Power of Chromium Plating Baths. H. L. Farber. *Metal Cleaning & Finishing*, Sept. 1929, pages 437–438.

Abstract of paper read before the American Electroplaters' Society, July 8–11, 1929. As a result of numerous experiments, concludes, among other things, that throwing power is determined almost entirely by the cathode efficiencies at the high and low current densities. High temperatures and current densities, dilute solutions of chromic acid, and low content of sulphate improve throwing power. Best throwing power was obtained in a bath containing 33 oz. per gal. of CrO_3, 0.17 oz. per gal. of SO_4, at 131° F. and current density of 325 amp./ft.^{2}. MS

Filter Costs Cut $67,527 Yearly in Sugar Plant. *Inco*, 1929, Vol. IX, No. 3, pages 9–24.

The Pennsylvania Sugar Co. in Philadelphia effected a great saving by substituting Monel Metal mesh for canvas filters. Maintenance and operating costs are less with metal filters. MLM

Monel Metal in Interior Decoration. *Inco*, 1929, Vol. IX, No. 3, pages 11–12.

Novel screens, mantels, lighting fixtures, and small pieces of furniture made of Monel metal are described. This metal harmonizes especially well with the modern interior decoration because of its silvery color and soft gleam. MLM

Aluminum and Its Alloys in Aircraft. T. W. Bossert. *Heat Treating & Forging*, Oct. 1929, Vol. 15, pages 1315–1316; *Metal Stampings*, Nov. 1929, Vol. 2, page 850.

Paper presented at meeting of American Electrochemical Society, Sept. 1929. See Metals & Alloys, Jan. 1930, Vol. 1, pages 325–326 for complete paper, Feb. 1930, page 385 for abstract. MS

HEAT TREATMENT

Hardening of Files without Decarburization in Salt Baths. (Die Härtung von Feilen ohne Entkohlung im Salzbad.) W. Beck & C. Albrecht. *Stahl und Eisen*, Oct. 3, 1929, Vol. 49, pages 1457–1458.

Investigations on decarburization in hardening plain carbon tool steel (1.45% C, 0.19% Si, 0.35% Mn) were made by using a special salt bath, the so-called Duo-ferrit-treating bath. Decarburization can be avoided in this bath and decarburization, up to a depth of about 0.2 mm. due to other causes can be restored. GN

Heat Treatment of Alloy Steels. W. H. Hatfield. *Fuels & Furnaces*, Sept. 1929, Vol. 7, pages 1355–1360.

Essential aspects in heat treating alloy steels are (1) adequate furnaces, quenching baths and mechanical means of efficient handling of the product, (2) adequate means of determining the temperature of the part being treated, (3) complete knowledge of the metallography of the steel being treated, (4) adequate knowledge of the allowance in time-temperature effect and speed of cooling to be made as regards the influence of mass,and (5) adequate means of testing the final product. MS

Comparative Investigations on the Heat Treatment of Case Hardened Steels. (Vergleichende Untersuchungen über die Wärmebehandlung eingesetzter Stähle.) H. Lüpfert. *Stahl und Eisen*, Nov. 28, 1929, Vol. 49, pages 1717–1724; *Iron & Coal Trades Review*, Dec. 27, 1929, Vol. 119, pages 9–86.

The importance of a correct heat treatment before and after case hardening is emphasized. A plain carbon steel (C: 0.10%, Si: 0.24%, Mn: 0.61% P: 0.041%, S: 0.035%) and a nickel-chromium steel (C: 0.10%, Si: 0.20%, Mn: 0.30%, P: 0.005%, S: 0.015%, Ni: 4.0%, Cr: 0.7%) were investigated. Space diagrams are developed to derive the grain size for various temperatures and times of annealing and various cooling velocities. How temperature and time of case hardening are to be chosen to produce a desired depth of case hardening with the lowest possible increase in grain size is discussed in relation to this diagram. An increase of the physical properties of the carbon steel but still more of the nickel-chromium steel is obtained when materials are drawn to 200° C. after being hardened. GN & RHP

Transmission Gears Annealed and Hardened with Great Accuracy. H. D. Martin. *Iron Trade Review*, Sept. 12, 1929, Vol. 85, page 649.

From *Black and White*, Sept. 1929. Gear blanks made from S.A.E. 6150 steel are annealed in a double-tunnel automatic electric furnace, tunnels being separated by a 12 in. wall. Chambers operate in opposite directions. Operation is automatically intermittent. Close control of time and temperature is required to produce the structure desired which is coarse lamellar pearlite, with some massive ferrite, and an absence of sorbite or spheroidal cementite. The gears are hardened by the duplex-method in cyanide, which removes the scale and imparts a slight skin hardness. A set of 4 electric rotary furnaces and 4 electrically heated cyanide pots are arranged so that there is a conveyor-type oil quench tank between a pair of furnaces and a cyanide pot near each discharge door of the rotary hearth. The gears are taken from the quench tank, washed, and given an oil draw. MS

Annealing

Continuous Heat Treatment of Sheet Metal. Edward S. Lawrence. *Blast Furnace & Steel Plant*, Sept. 1929, Vol. 17, pages 1346–1349; Oct. 1929, pages 1497–1499, 1504; *Heat Treating & Forging*, Sept. 1929, Vol. 15, pages 1160–1163, 1168; Oct. 1929, pages 1296–1298, 1306; *Sheet Metal Industries*, Feb. 1930, Vol. 3, pages 543–547.

Continuous normalizing is being applied to medium carbon steels as well as to low carbon steels used for deep stamping work. Normalizing results in the elimination of internal strains and the formation of a fine grained structure. The heating above the A_3 range and the rapid cooling with exclusion of air which is thus necessitated, are carried out in continuous furnaces. These may have hearth widths from 60 to 96 in. and heating zones from 40 to 100 ft. long with communicating cooling chambers as long as desired. The conveying mechanisms are of various types. The speed at which the material can be conveyed through the normalizers depends principally on: (1) Hearth width and length of heating zone; (2) carbon content of steel; (3) elimination of internal strains; (4) grain size desired; (5) temperatures in heating zone; (6) rate of preheating; (7) time rate of cooling; (8) thickness of metal. The continuous normalizer can be adapted to continuous open annealing with the following advantages over box annealing: (1) uniformity of anneal to all portions of sheet; (2) equivalent fuel consumption and tonnage cost; (3) reduced space requirement for heat treatment; (4) elimination of boxes and their high depreciation; (5) greatly increased production in less time. Describes methods of open annealing deep drawing sheet, strip and thin gage packs to be coated with tin, lead or zinc. MS

Improvement of Toughness of High Speed Steel by Carbide Annealing. (Verbesserung der Zähigkeit von Schnellarbeitsstahl durch Karbidglühung.) R. Hohage & R. Rollett. *Archiv für das Eisenhüttenwesen*, Sept. 1929, Vol. 3, pages 233–239; *Stahl und Eisen*, Oct. 17, 1929, Vol. 49, pages 1519–1520.

In spite of proper annealing an unexpected high brittleness in high speed steels is often observed. The investigations prove that the temperature of hot working has considerable influence on the mentioned phenomenon. The following table shows (Brinell hardness of sheets 5.5 mm. thick) the annealing temperature is most important. Brinell hardness of high speed steel sheets (0.72% C, 0.15% Si, 0.30% Mn, 4.49% Cr, 19.60% W, 0.37% Mo, 1.58% V) in the as rolled condition and after annealing at various temperatures in relation to the finish rolling temperature are given.

Finish rolling temperature	as rolled	Brinell hardness annealed at ° C.				
		700°	750°	800°	850°	900°
cold (400° C.)	652	351	321	262	255	262
medium (700° C.)	600	351	321	269	255	262
hot (900° C.)	652	352	321	255	248	262

The highest degree of softness is reached at 850° C. The toughness was investigated by means of bending tests. Softness and toughness are not the same. The best values of toughness are obtained in rolling at medium temperatures (700° C.) and annealing at 850° C., whereas the best values of softness are obtained at the same annealing temperature with the hot rolled (900° C.) sheets. The best results for toughness and softness are obtained when, after annealing, the sheets are quenched in water from temperatures below the transformation point. This treatment is called "carbide annealing." Microscopic examinations result in the statement that up to 650° C. quenching temperature the carbides are coarser, from 650–750° C. quenching temperature finer. GN

Malleable Iron—Short Cycle Anneal. I. R. Valentine. *Heat Treating & Forging*, Oct. 1929, Vol. 15, pages 1344–1345; *Iron Trade Review*, Nov. 21, 1929, Vol. 85, pages 1305–1306.

Paper presented at National Metals Congress, Sept. 1929. See Metals & Alloys, Nov. 1929, Vol. 1, pages 233–234. MS

Hardening

Procedure in Hardening Steel Tools. Arthur H. Hert. *Heat Treating & Forging*, Oct. 1929, Vol. 15, pages 1291–1292.

One of the most important points in securing satisfactory results is proper heating. Most of the failures such as cracking, warping or distortion and shrinkage of holes are, aside from defective steel, due to improper heating. Unequal expansion causes most of the trouble. The material should be heated from a cold state with continual rise of temperature to the critical point, so that all parts of it from surface to center are at the same temperature. In quenching, steel should be 20–50° F. degree above critical point to allow for loss while being taken from the fire to the bath. MS

Methods in High Speed Steel Hardening. L. M. Jordan. *Heat Treating & Forging*, Oct. 1929, Vol. 15, pages 1350, 1353.

Largely a review of a paper by E. Zingg, P. Oberhoffer & E. Piwowarksy in *Stahl und Eisen*, May 16 and 23, 1929. See Metals & Alloys, Aug. 1929, Vol. 1, page 79. MS

Case Hardening and Nitrogen Hardening

Hardening Steel in Ammonia Gas. *Iron Trade Review*, Sept. 5, 1929, Vol. 85, pages 597–598.

American Metal Treatment Co., in nitriding machinery steel uses relatively low ammonia concentration, low temperatures and longer time, these varying with the different classes of work. For example, sheet steel fan blades used in a city gas blower are inserted between spacers on an endless chain and are passed through the nitriding furnace. They are exposed to ammonia at 1100° F. and 2 lb. pressure. One hour's exposure increases surface hardness 75%. Combination of case hardening with city gas, quenching, and afterward nitriding to increase corrosion resistance, gives excellent results. The low gas concentration and greater time element give a closer knit structure between the case and the base metal. The relatively low temperatures employed prevent distortion of the work. MS

JOINING OF METALS AND ALLOYS

Welding and Cutting

Welding of Stamped and Formed Parts Made of Strong Aluminum Alloys. *Metal Stampings*, Oct. 1929, Vol. 2, pages 805–806.

In welding joints of strong Al alloy stock, care should be taken in the design and procedure to facilitate welding, to avoid difficult and complicated joints and to take care of expansion and contraction. Tack-welding should be avoided in making tanks. The welding rod recommended for all welds is one of any alloy which contains 5% Si. For best results the entire part, after welding, should be heated in a suitable furnace to 890–940° F., and then quenched in cold water or oil. MS

Welding of Stamped and Formed Aircraft Parts. S. C. Clark & W. I. Gaston. *Metal Stampings*, Sept. 1929, Vol. 2, pages 709–712.

From paper presented at a meeting of the Aeronautic Division, American Society of Mechanical Engineers, in St. Louis. Steel tubing is coming into common use for fuselage construction and with this, there is a trend toward general use of welding. It is desirable to establish standard designs for welded joints and to this end research is being conducted. Suggests improvements in welding practice that will add safety and insure uniformly well-made welds. MS

Arc Welding in Machine Construction. (Die Lichtbogenschweissung im allgemeinen Maschinenbau.) C. Ritz. *Siemens Zeitschrift*, Nov. 1929, pages 752–758; *Zeitschrift Verein deutscher Ingenieure*, Dec. 7, 1929, Vol. 73, pages 1740–1741.

The methods of arc welding, including the apparatus used as automatic arc welding equipment are described. The advantages are outlined and illustrated by numerous examples. The importance of material, electrodes and welding machines on the quality of welds is discussed. Different types of transformers are described. GN

Arc Welding in Electric Machinery Construction. (Die Lichtbogenschweissung im Elektro-Maschinenbau.) W. Raupach. *Siemens Zeitschrift*, Nov. 1929, pages 758–761.

Welding is applied economically on heavy parts made from steel shapes or sheets when cost for mechanical work and welding are low. Simple shapes of medium size are economically welded when the number of pieces does not exceed 10 to 20 pieces. Also small parts with difficult shapes can be economically welded in single pieces. GN

Tensile Strength of Pipe Connections. (Die Festgikeit und Beschaffenheit bisheriger und neuerer Muffenverbindungen und Anleitung zur sachgemässen Verschwiessung.) F. Weckwerth. *Archiv für das Eisenhüttenwesen*, Sept. 1929, Vol. 3, pages 185–198; *Stahl und Eisen*, Oct. 10, 1929, Vol. 49, pages 1491–1493.

Description and investigation of welded tube connections, according to old and new methods of manufacturing. Training of welders is emphasized. GN

Atomic Hydrogen. Its Application to Welding of Metals. (L'hydrogene atomique. Application a la soudre des metaux.) Jean Brillie & Ernest Morlet. *Revue de Metallurgie*, Dec. 1929, Vol. 26, pages 680–688.

A critical review of Langmuir's theory of atomic hydrogen arc welding. JDG

Welding Metal Furniture. A. F. Davis. *Journal American Welding Society*, Jan. 1930, Vol. 9, pages 28–37.

Oxyacetylene welding with steel welding rod is advised if the furniture is to be enameled. With other types of finish, bronze welding is employed. HWG

An Experimental Investigation of the Strength of Welds as Affected by Coatings of Rust, Paint and Oil Upon the Welded Surface, G. F. Rogers. *Journal American Welding Society*, Jan. 1930, Vol. 9, pages 38–40.

Abstract of M. S. thesis. Joints rated in the following order: fresh red lead paint, clean metal, fresh oiled, rusted, dry oil, dry paint. Five specimens of each group were tested. Averages varied only from 44,000 48,000 lb./in.^{2}, minima from 38,000 to 45,000. Accidental variations in welding probably outweigh the variables studied. It is easier to do a good job on clean metal. HWG

Welding Development in 1929. Editorial. *Journal American Welding Society*, Jan. 1930, Vol. 9, pages 41–64.

Summary pointing out increase in welding of steel in building construction, ship construction, etc., by all types of welding. HWG

How to Weld Galvanized Iron. A. G. Wikoff. *Journal American Welding Society*, Jan. 1930, Vol. 9, pages 23–27. Discussion, pages 34 and 35.

Welding with bronze is recommended. Such welds are said to be three times as strong as soldered double-lock seams. The places where the zinc coating is burnt off may be coated externally with aluminum paint. They exert no worse effect on pipe than the baring of the base metal by cutting threads HWG

Report of Tests Made Upon Welded Joints for Boston Section of American Welding Society. *Journal American Welding Society*, Jan. 1930, Vol. 9, pages 18–22.

Sketches and tensile test data on 15 welds. HWG

Welding on High Pressure Boilers. L. Hofmann. *Journal American Welding Society*, Jan. 1930, Vol. 9, pages 7–16.

Describes oxyacetylene welding of seamless 0.32 C steel tubing used in a boiler operating at 1700 lbs./in.^{2} and 930° F. Sample welds were tested in tension at the start and, after 5000 hours of service, welds were cut out and tested. The unwelded material had about 80,000 lbs./in.^{2} at room temperature, the original weld 20,000 to 40,000 (one test showing only 20,000) at 1020° F., and the used weld 30,000 to 40,000 lbs./in.^{2} at 1020° F. After 10,000 hours service, all the many hundreds of welds are intact. Arc welding should not be used for these tubes. While the welds described are oxyacetylene, Hofman says that flash resistance welding gives the best results of all. Welds in high pressure tubing should be annealed. Micrographs of the weld structure are shown. HWG

The Electric Arc-Welding Process in Pipe Line Construction. J. F. Lincoln. *Gas Age-Record*, Jan. 25, 1930, Vol. 65, pages 105–107.

Less than 2 years ago, the first arc-welded pipe line was completed. This was the 7-inch line for the transportation of gas from Lamkin to Hodge, Louisiana. The most recent arc-welded pipe line is a 12-inch line being constructed for the Compania Mexana de Gas, a subsidiary of the United Gas Company. This line will be 165 miles long, running from Aquilares to Roma, Texas; then, across the Rio Grande River, via the International Bridge to San Pedro, Mexico; and thence to Monterrey, Mexico. The chief features of the present practice in arc-welding are: the use of bell and spigot joints with preferably a welding dam on the spigot end; the use of a mild steel, loosely coated welding rod of $^{3}/_{16}$ to $^{1}/_{4}$ inch thickness; a six-cylinder gasoline engine running a 300-ampere machine; and the use of caterpillar tractors in transporting machines, etc. General details are given.—*Abstract Bulletin, National Tube Company.*

FURNACES AND FUELS

Melting Aluminum in Electric Furnaces. (La fusion de l'aluminium au four electrique.) A. Balin. *Journal du Four Electrique*, Dec. 1919, Vol. 38, page 416.

A brief description of Russ system melting furnaces of concave and flat bottom type. JDG

Recent Developments in Melting and Annealing Non-ferrous Metals. Robert M. Keeney. *Technical Publication* No. 286, *American Institute Mining & Metallurgical Engineers*, Feb. 1930, 16 pages.

Copper alloys, such as nickel silver, can be most economically melted in a vertical ring induction furnace except where only small quantities are produced. Electrically heated pots are coming into extensive use for melting stereotype metal. Gas fired furnaces have recently replaced many wood fired furnaces for the finishing anneal of brass. Electric furnaces are being used for bright annealing in steam. JLG

Temperature Distribution in Combustion Furnaces. M. H. Mawhinney. *Fuels & Furnaces*, Oct. 1929, Vol. 7, pages 1581–1586.

From paper before Iron and Steel Division of the American Society of Mechanical Engineers, Sept. 11–13. Describes tests carried out on a furnace arranged for direct firing, side firing and under firing. Deals with effect, method of firing, temperature in furnace, time, furnace dimensions and material in furnace on temperature distributions Presents results in tables and charts. MS

Electric Heating Units for Special Applications. Robert Daniels. *Fuels & Furnaces*, Dec 1929, Vol. 7, pages 1933–1934.

Stock cast-in electric immersion electric heating units are very satisfactory for melting white metals such as Pb, Sn, solder, type metal, etc. MS

Electric Melting Pots for Babbitting. H. K. Sellick. *Fuels & Furnaces*, Dec. 1929, Vol. 7, pages 1927–1928.

Tests show that babbitt must be brought up to a definite temperature and poured at the correct temperature of 860–896° F. to secure the greatest life of a bearing Electrically heated pots with automatic temperature control give very satisfactory results using the cheaper lead base babbitts. MS

Uses Rotary Foundry Melting Furnace. *Iron Age*, Dec. 12, 1929, Vol. 124, page 1586.

Abstract translation of article in Kaiser Wilhelm Institut für Eisenforschung, No. 131. Discusses a new type of furnace known as the Brackelsburg furnace used in the production of high quality gray and malleable castings. See Metals & Alloys, Dec. 1929, Vol. 1, page 293. VSP

Research Gives Gas New Prestige. *U. G. I. Circle*, Feb. 1930, pages 12–15.

Report of 3 years work carried out by a committee of the American Gas Association, which investigated the utilization of gas in the industries. Work on the high temperature use of gas was carried out by the Department of Engineering Research, University of Michigan and the Surface Combustion Co. The investigations of interest to metallurgy covered the advantages of gaseous atmosphere for the better heat treatment of steel; brass smelting; bright annealing; stereotype melting.

Improvement in Pack Heating. Charles Longenecker. *Blast Furnace & Steel Plant*, Nov. 1929, Vol. 17, pages 1661–1663.

Better quality and lower cost of production is obtained by means of the double mill system and continuous pack heating furnaces. Material is moved through the furnace on chain conveyors. About 900 cu. ft. of gas are burned per ton of sheets heated. MS

Vertical Gas Carburizers Used in Heat Treatment of Steering Gear Parts. *Fuels & Furnaces*, Sept. 1929, Vol. 7, pages 1418–1420.

Vertical retort furnaces have been installed, provided with heat exchangers for pre-heating of charge by utilizing waste heat from carburized parts placed in cooling chamber. The temperature of carburization is 1650° F. The charge is pre-heated to 500–600° F. The parts are hardened in a cyanide bath at 1450° F. quenched in water and tempered in a salt bath at 325° F. MS

Pusher Type Furnace Used in Heat Treating Forgings. *Fuels & Furnaces*, Sept. 1929, Vol. 7, pages 1421–1424, 1428.

Furnace installation consists of continuous type, oil-fired billet heating and normalizing furnaces; gas-fired, in-and-out type forging furnace; electrically-heated, continuous type hardening and tempering furnaces; electrically heated, in-and-out type hardening furnace and electrically heated nitriding furnace. MS

Mounts Furnaces on Springs to Avoid Vibration Stresses. J. B. Nealey. *Iron Trade Review*, Dec. 12, 1929, Vol. 85, pages 1497–1501. *Fuels & Furnaces*, Dec. 1929, Vol. 7, pages 1859–1862; Feb. 1930, Vol. 8, pages 229–230.

Insulated, counterflow, slot-type furnaces with preheating and heating chambers are used for heating front-axle stock prior to forging. Furnace proper is mounted on springs while arch is suspended from steel work by hangars. Nearly all forgings are normalized in furnaces with steel encased walls and having 2 zones. Some stock is heated to 1560° F. and some to 1550° F. for 1 hr. Discharge temperature is 1000° F. After normalizing work is hardened by heating to 1470–1500° in 2 hr., and quenching in caustic solution. It is then heated in a drawing furnace at 980–1000° F. for $2^1/_2$ hr. Cyanide hardening is carried out at 1480–1650° F. for 4–20 min. Heavy work is heat treated in car-type furnaces. Quenching mediums are either oil or caustic solutions. Front axles are heat-treated in regenerator-type furnaces. Hardening temperature is 1470–1500° F. and time is $2^1/_2$ hr. For heat treating rear axle, a furnace that both hardens and draws has been developed. Hardening heat is 1490° F. and drawing temperature is 680° F. MS

PLANTS AND LABORATORIES

Developments in the Production of Stainless Steel. *Edgar Allen News*, Feb. 1930, Vol. 8, pages 559–561.

Stainless steel is more difficult to manufacture than ordinary steel. This article describes and illustrates the process. MLM

Manufacture of Machine Gun Parts. J. B. Nealey. *Army Ordnance*, Jan.–Feb. 1930, pages 268–270.

The machining and heat treating of machine gun parts is described.

Heat-Treating in a Model Small Plant. George S. Brady. *American Machinist*, Dec. 19, 1929, Vol. 71, pages 991–994.

Describes a modern plant. RHP

Die Castings are Produced from Various Non-ferrous Alloys. J. B. Nealey. *Foundry*, Dec. 1, 1929, Vol. 57, pages 1022–1024.

Low temperature alloys are cast in permanent molds. Temperature 1400° F. is the limit of die casting alloys at the present. Describes the method and the alloys used. Alloys of 4 different metal bases are used: Aluminum base, zinc base, tin base and lead base. The company makes die castings for a wide diversity of industries of which the automotive stands first. At present portion of plant is being fitted for the manufacture of aluminum cooking utensils. VSP

Aeronautical Aluminum Foundry. Fay Leone Faurote. *Iron Age*, Dec. 12, 1929, Vol. 124, pages 1587–1592.

Describes a new aeronautical foundry. The new plant is unique in that it has a basement, it is so light that artificial light ordinarily is not needed and there is almost a complete absence of fumes and odors arising from core-making and casting. The plant contains 128,000 sq. ft. of space. All castings for the various types of Wright airplane engines are made in this plant. Gives layout of the plant and equipment used. VSP

MACHINERY AND SUPPLIES

Plant Equipment

Cleaning Room Equipment for Small Steel Casting Manufacture. *Research Group News*, Jan. 1930, Vol. 6, pages 277–283.

Smaller castings require more thorough finishing to suit requirements of purchaser. Several photographs are given of cleaning room equipment such as tumbling barrels, and blasting equipment. MLM

MISCELLANEOUS

Order of Removal of Metals from Amalgams. A. S. Russell. *Journal Chemical Society*, London, Oct. 1929, pages 2398–2401.

The statement made in earlier papers, of the order in which metals are removed by oxidizing solutions from mercury in which they are dissolved or suspended, is corrected, the corrected order being zinc, cadmium, manganese, thallium, tin, lead, bismuth, copper, chromium, iron, molybdenum, cobalt, mercury, nickel and tungsten.

Impact of Spheres of Soft Metals. J. P. Andrews. *London, Edinburgh, & Dublin, Philosophical Magazine & Journal of Science*, Dec. 1929, Vol. 8, Supplementary No., pages 781–800.

Investigation of the duration of contact during collision of 2 equal spheres of the same material. Partial discharge of a condenser is used to measure the duration. For aluminum, tin, brass, babbitt and a lead-tin alloy a law of the form $t = t_0 + a/v^n$ is obtained, where v is the relative velocity at impact, t_0, a, and n are constants. Zinc follows a similar law but the constants cannot be accurately determined. Gives a description of the flattened areas remaining on the spheres after collision and offers an explanation of the rim which surrounds them. RHP

Photoelectric Thresholds of the Alkali Metals. N. R. Campbell. *London, Edinburgh & Dublin. Philosophical Magazine*, Nov. 1929, Vol. 8, pages 667–668.

The theory of the photoelectric effect put forward by Ives and Olpin seems to imply that the threshold frequency of a thin film of the alkali metals should be independent of the surface upon which it is deposited. Although this may be true when the surface is gas-free, it is not the case when the support is a metal surface deliberately oxidized. RHP

Electricity is Finding Wider Use in Metalworking Industries. *Iron Trade Review*, Nov. 21, 1929, Vol. 85, pages 1314–1315.

Report of the third annual conference held in Pittsburgh, Nov. 13–14, and sponsored by Pennsylvania State College and the Association of Iron and Steel Electrical Engineers, with abstracts of papers presented. These deal with welding and heating. MS

Developing Methods to Prevent Waste in Steel Industry. Frank Parrish. *Heat Treating & Forging*, Dec. 1929, Vol. 15, pages 1594.–1597. Condensed. *Iron Trade Review*, Nov. 7, 1929, Vol. 85, pages 1176–1178. *Rolling Mill Journal*, Nov. 1929, Vol. 3, pages 479–482.

From paper before American Iron & Steel Institute, entitled "Waste Prevention and Salvage as Applied to the Steel Industry," Oct. 1929. See Metals & Alloys, Feb. 1930, Vol. 1, page 390. MS

Study of Fatigue Cracks in Car Axles. H. F. Moore, S. W. Lyon, & N. J. Alleman. *Heat Treating & Forging*, Dec. 1929, Vol. 15, pages 1573–1578, 1582.

Abstract of University of Illinois Engineering Experiment Station Bulletin No. 197. See Metals & Alloys, Feb. 1930, Vol. 1, page 390. MS

Development and Installation of the Hawkesworth Detachable Bit. Chauncey L. Berrien. *Technical Publication* No. 274, *American Institute Mining & Metallurgical Engineers*, Feb. 1930, 29 pages.

Data showing the advantages derived from the use of the detachable bit are given. Details of manufacture, including heat treatments are given. JLG

Directed Stress in Copper Crystals. C. H. Mathewson & Kent R. VanHorn. *Technical Publication* No. 301, *American Institute Mining & Metallurgical Engineers*. 26 pages.

Single crystal copper rods were produced at solidification and blocks whose faces were parallel to definite crystallographic planes were cut by means of a special miter box. These blocks were deformed in a manner calculated to produce twinning, but twinning, as indicated by visual and X-ray examination could not be produced by deformation alone. JLG

Electrolytic Iron from Sulphide Ores. Robert D. Pike, George H. West, L. V. Steck, Ross Cummings & B. P. Little. *Technical Publication* No. 268, *American Institute Mining & Metallurgical Engineers*, Feb. 1930, 35 pages.

The production of electrolytic iron is reviewed. The operation of a pilot plant in which iron and copper are leached from a sulphide ore, the copper cemented out, and the iron deposited electrolytically is described. The iron could be produced in dense plates, which when annealed, could be cold rolled with ease. Such iron was very pure and was, therefore, softer than commercially pure iron and had superior magnetic properties. JLG

Finishing of Metals in Various Odd Colors. Thomas A. Gardner. *Metal Cleaning & Finishing*, Nov. 1929, Vol. 1, pages 593–594, 612

For various shades of green on brass a solution is used consisting of 1 gal. H_2O, 4 oz. $CuSO_4$, $2^1/_2$ oz. $NiSO_4$, and $1^1/_2$ oz. $KClO_3$. For brown colors on metals other than Cu, the article is just flashed in Cu, and this solution used. A bath of 1 gal. H_2O, 1–6 oz. $NiSO_4$ and 6 oz. $Na_2S_2O_3$ will give antique bronze on brass. Blacks, browns and greens can be obtained with 1 gal H_2O, 4 oz. $CuSO_4$, $1^1/_2$ oz. $NiSO_4$, $^1/_2$ oz. NH_4Cl, $1^1/_4$ oz. $Cu(C_2H_3O_2)$, 1 oz. $KClO_3$ and 2 oz. $Nz_2S_2O_3$. Solutions must be used at 180–200° F. and the compositions as specified. Gives formulas and directions for obtaining various pleasing finishes. MS

A Study of Tin-Base Bearing Materials. G. B. Karelitz & O. W. Ellis *American Machinist*, Dec. 19, 1929, Vol. 71, page 1003.

Abstract of a paper presented at the annual meeting of the American Society of Mechanical Engineers at New York City, Dec. 2-6, 1929. Discusses the nature of babbitt bearing failures and the effect of the composition of the metal on the tendency to fail by "Wiping." RHP

Plastic Flow of Metals. A. Nadai. *Metal Stampings*, Dec. 1929, Vol. 2, pages 955–958.

Abstract of paper read before American Society of Mechanical Engineers, Dec. 2–6. Discusses the mechanical conditions and rules of plastic flow. Treats of the cases of cylinders and of pure bending of bars. Discusses methods of finding residual stresses after severe plastic deformation. MS

FOUNDRY PRACTICE AND APPLIANCES

Conversion of Synthetic Gray Iron in the Cupola. W. J. Merten. *Fuels & Furnaces*, Sept. 1929, Vol. 7, pages 1367–1370.

A high silicon iron of pearlitic structure can be economically produced from a cupola without alloying elements such as Mn, Cr, Ni, Mo, etc. Sheet punching and shearing scrap is charged in bales. The height of the coke bed must reach at least 30″ above the upper row of tuyères. Charge of iron that can be used is 1–$1^1/_4$ lbs./in.^{2} of cupola area at the melting zone. The iron-coke ratio between charges is 8:1. Charge also consists of 2–3 limestone and enough ferromanganese to raise this element to about 0.6% in the final product. Blast pressure is somewhat lower than in ordinary gray iron melting, but reduced volume of air must be avoided. MS

Monel Metal and Nickel Foundry Practice. E. S. Wheeler. *Technical Publication* No. 298, *American Institute Mining & Metallurgical Engineers*, Feb. 1930, 9 pages.

Directions are given for producing satisfactory castings from nickel and monel metal. The importance of allowing for the shrinkage of $^1/_4$ inch to the foot is emphasized. JLG

High Grade Cast Iron Produced by Large Steel Scrap Additions. R. S. MacPherran. *Foundry*, Jan. 1, 1930, Vol. 58, pages 112–113.

Abstract of paper presented at the Chicago convention of the American Foundrymen's Association. Discusses method of operation in producing high grade cast iron. The steel scrap used is about $^1/_2$–$^1/_3$ railway springs and the remainder is steel rails. A list of 63 test bars, with their tensile tests and chemical analysis has been compiled. The average tensile strength for the 63 test bars was 58,300 lbs./in.^{2}. VSP

REFRACTORIES AND FURNACE MATERIALS

High Temperature Annealing of Steel Castings. William J. Merten. *Fuels & Furnaces*, Oct., 1929, Vol. 7, pages 1531–1532.

Abstract of paper before American Society for Steel Treating, entitled "Improving of Refractory Lining of Heat Treating Furnaces for High Temperature Annealing of Steel Castings." Sept. 9–13. See Metals & Alloys, Jan. 1930, Vol. 1, page 346. MS

GASES IN METALS

A Theory Concerning Gases in Refined Copper. A. E. Wells & R. C. Dalzell. *Technical Publication* No. 270, *American Institute Mining & Metallurgical Engineers*, Feb. 1930, 15 pages.

Both deoxidized and oxidized (0.06% O_2) copper samples were melted in atmospheres of CO_2, CO, N_2, H_2O and H_2. The density of the resulting ingots was determined. One series was made in graphite crucibles and another in fused silica crucibles. To account for differences in porosity observed the authors advance the theory that the oxide in molten copper is in a colloidal state and that these colloidal particles have the ability to adsorb water and carbon dioxide. It is also suggested that in aluminum-silicon alloys the silicon is in a colloidal state in the molten aluminum and that in modification the sodium acts as a peptizing agent. JLG

Oxygen Causes Hard Iron. James A. Lannigan. *Foundry*. Dec. 1, 1929, Vol. 57, pages 1017–1018.

Deals with the problem as to what element in pig iron is present in such quantity as to render the iron unfit for foundry use. Considers experiences of a number of plants throughout the country. Author's conclusion is that oxygen in solution as an oxide is the cause of the trouble. Reference is made to Dr. Moldenke's paper published in 1927 on "Evaluation of foundry pig irons." VSP

Blistering of Metal during Annealing. Anson Hayes. *Fuels & Furnaces*, Oct. 1929, Vol. 7, pages 1537–1538, 1576.

From paper read before American Society for Steel Treating entitled "Conditions Necessary for Blistering of Metal during Processing," Sept. 9–13. See Metals & Alloys, Jan. 1930, Vol. 1, page 345. MS

INSPECTION

X-Ray Inspection of Castings. Ancel St. John. *Fuels & Furnaces*, Sept. 1929, Vol. 7, pages 1371–1372, 1407–1408.

The value of the intelligent use of X-ray inspection in the foundry lies in its ability to teach how to make better castings, to prove that individual castings are sound, and to convince prospective customers that such castings are suitable for severe working conditions. MS

Practical Aspects of Spark Testing. Walter G. Hildorf & C. H. McCollam. *Iron Age*, Oct. 10, 1929, pages 953–956.

Spark testing when carefully applied is a cheap, reliable and fast means of steel classification. The basic theory is that small particles torn loose, and if tearing is sufficiently violent heat is formed. As the hot particles fly through air they come in contact with air and iron oxide is formed. Author's theory is that the carbon present in the metal units with oxygen and carbon dioxide is formed at a rate faster than the formation of iron oxide. High carbon steel throws off more sparks than low carbon steel because of greater amount of carbon dioxide. VSP

The Inspection of Metals and Their Alloys. L. W. Johnson. *Automobile Engineer*, Dec. 1929, Vol. 18, pages 511–518.

Abridgement of a paper presented before the Institution of Automobile Engineers. An inspection system is necessary in the aircraft and automobile industry to insure good material and so maintain the reliability of the engine or other part. The paper briefly reviews the various types of material tests and also discusses different kinds of defects of metals and their alloy. Methods of testing and results secured are given for: (1) Tensile strength; (2) Hardness; (3) Impact; (4) Fracture. (5) Bend and reverse bend; (6) Torsion; (7) Fatigue; (8) Magnetic test; (9) Magnetic analysis; (10) Pickling and etching; (11) Sulphur prints; (12) Macro-etching. Materials tested included: (1) Bar material; (2) Castings; (3) Tubes; (4) Wire. RHP

Steel Inspection Standards for Roller Bearings. A. S. Jameson. *Transactions American Society for Steel Treating*, Dec. 1929, Vol. 16, pages 937–949.

This paper gives the methods used for the inspection of S. A. E. 1015 forging quality steel used for roller bearings. Hot acid etching for pipes and blow holes, microscopic methods for determining non-metallics and the McQuaid-Ehn test are described and illustrated. A short discussion is given on the production of a desirable steel for carburizing. WHK

EFFECTS OF ELEMENTS ON METALS AND ALLOYS

Molybdenum in Cast Iron. E. K. Smith & H. C. Aufderhaar. *Iron Age*, Dec. 5, 1929, Vol. 124, pages 1507–1509.

Discusses the importance of molybdenum as an alloying element. The supply of molybdenum ores in the United States is the largest in the world. Information on molybdenum in cast iron is very meager. Cites a few references available. Describes series of experiments conducted by the authors and gives results as to machinability, physical properties and structure. Concludes that moderate amounts of molybdenum have a beneficial effect on physical properties of cast iron, but the increased cost is a detriment. Molybdenum is of advantage where decreased weight, increased strength or shock resistance is important. VSP

Molybdenum in Malleable Cast Iron. Fred L. Coonan. *Heat Treating & Forging*, Dec. 1929, Vol. 15, pages 1561–1563.

Deals with possibility of improving properties of malleable iron by means of Mo. Results of physical tests indicated that Mo in small quantities tends to raise the yield point, increase the tensile strength and improve the elongation. Much more than 0.50% results in a loss in ductility. Microscopic examination shows that Mo tends to retard the decomposition of cementite into iron and temper carbon. The slight increase in ductility with only small amounts of the element is probably due to the refinement of the ferrite, no tendency to promote the formation of smaller grains. MS

Effects of Oxidation and Certain Impurities in Bronze. J. W. Bolton & S. A. Weigand. *Technical Publication* No. 281, *American Institute Mining & Metallurgical Engineers*, Feb. 1930, 17 pages.

A bronze that was remelted twice in an oxidizing atmosphere became very sluggish, had a low strength and apparently an increased shrinkage. The effects of small amounts of silicon, sulphur and aluminum on bronzes melted in a reducing atmosphere were determined. Small amounts of silicon and sulphur did not have a marked effect, but very small amounts of aluminum were harmful. Numerous photomicrographs are given. JLG

The Influence of Silicon in Foundry Red Brasses. H. M. St. John, G. K. Eggleston & T. Rynalski. *Technical Publication* No. 300, *American Institute Mining & Metallurgical Engineers*, Feb. 1930, 18 pages.

Silicon has been suspected as being the cause of intercrystalline porosity in leaded brasses and bronzes. Small amounts of silicon when added to copper containing zinc or tin did no thave a deleterious effect on the resulting castings, but with any of the alloys containing lead in appreciable quantities porosity resulted. In practice the silicon may come from scrap that has been dioxidized with silicon or by reduction in the electric melting furnace. The silicon may be removed by selective oxidation by the addition of an alkali or alkali-earth sulphate. JLG

Effect of Composition on Hardness of Tungsten Steels. W. Zieler. *Iron Age*, Dec. 12, 1929, Vol. 124, page 1595.

Abstract translation of article in *Stahl und Eisen*, July 25, 1929, Vol. 49, pages 1083–1084. Annealing and cooling are important in the formation of carbides in this system. In the intermediate and higher tungsten steels, normal cooling favors the formation of double carbide. With longer time near the critical temperature and slower cooling, the double carbide tends to split off more or less WC. Small additions of chromium tend to prevent decomposition and splitting off of WC. The phases present may be classified as Fe_3C, Fe_2W, WC and two double carbides. Tabulates results of test. VSP

Molybdenum Steels Gaining Favor. E. E. Thum. *Iron Age*, Jan 9, 1930, Vol. 125, pages 141–144, 201–202.

High molybdenum alloys have been made commercially by the crucible process many years ago. The first electric furnace heat of low molybdenum steel was made in Dec. 1927, while open-hearth production started in May 1918. Both events took place at the United Alloy Steel Corporation, Canton, Ohio. Effect of adding molybdenum to alloy steels is: (1) Its ability to induce air hardening and hardening at depth; (2) Quenched alloy steels with molybdenum hold their hardness after higher drawing temperatures. Free from "temper brittleness" which occasionally affects chromium and chromium-nickel steels; (3) Molybdenum forms solid solutions with iron and widens temperature range for hot working and heat treating; (4) Steels with 0.3 percent of molybdenum roll and drop-forge well; (5) It cold works well; (6) Chromium steels with molybdenum machine more easily than nickel-chromium steels without it; (7) Principal effect on tensile properties of alloys steels is to increase the % reduction of area; (8) Has no specific influence in resisting repeated or alternating stresses. Lists some of the important uses and tabulates the chemical and physical properties of the various alloy steels containing molybdenum, and based on S. A. E. specifications. VSP

LEACHING

Factors Governing the Entry of Solutions into Ores During Leaching. John D. Sullivan, Walter E. Keck & George L. Oldright. *Technical Paper* No. 441, *United States Bureau of Mines*, 1929, 38 pages.

The laws of capillary rise do not govern the ingress of solutions into ores since variation of the surface tension of the penetrating liquid has no effect on the rate. The solubiliy of the gas within the rock pores is the limiting factor. For example, 95% penetration with a certain ore normally took 60 hours. When the air was replaced with sulphur dioxide, the same effect could be accomplished in 4–9 hours. The relationship of time of saturation to size of particle is not linear. Greater and more rapid penetration is obtained at lower temperatures. AHE

Factors Governing Removal of Soluble Copper from Leached Ores. John D. Sullivan & Alvin J. Sweet *Technical Paper* No. 453, *United States Bureau of Mines*, 1929, 26 pages.

The relationship of time of diffusion of copper salts from a leached ore to size of particle is nearly linear. Low temperatures retard the removal of the salts. Alternate wetting and drying reduces the time for removal to 15–20% of that necessary in flood washing. AHE

REDUCTION METALLURGY

Effect of Sized Ore on Blast-Furnace Operation. S. P. Kinney. *Technical Paper* No. 459, *United States Bureau of Mines*, 1930, 92 pages.

Operation with 2 or 3 sizes of ore, in which each size was charged separately and in rotation, resulted in decreased coke consumption and increased iron production over operation with 1 size only. Decrease in over-all size of ore improved production. A greater burden can be carried with than without layer filling due to better gas-solid contact. The carbon monoxide to carbon dioxide ratios in the top gas when operating with 1, 2 and 3 sizes of ore were 2.68, 2.20 and 1.54, respectively, indicating better fuel economy with sizing. The average particle size of ore with 1, 2 and 3 sizes of ore was 1.6, 1.56 and 1.4 inches, respectively. Gas samples collected at a plane 3 feet below the top of the stock showed a fairly uniform CO_2 content and an average CO – CO_2 ratio of 1.50 (variation of 13%). Temperatures were 400° F. at the inwall and 900° F. at the center. Gas flow was fairly uniform across this plane. These results are far superior to data from other furnaces and point to the advantages of sizing the ore. About 20% of the reduction was carried on between the planes 3 feet and 21 feet 7 inches below the stock line and 76.4% between the latter and the top of the bosh. AHE

Flow of Gases Through Beds of Broken Solids. C. C. Furnas. *Bulletin* No. 307, *United States Bureau of Mines*, 1929, 144 pages.

The results of this theoretical study apply to blast furnace practice. The laws for fluid flow through conduits are not applicable to the tortuous flow through beds or broken solids. The formula $\Delta P = ARB$ has been derived, where A and B are constants for any particular condition, R is the rate of flow and ΔP is the pressure drop per unit of length. The report is concerned with the variation of A and B under different conditions. Nine variables were studied, using air, hydrogen and carbon dioxide: (1) density of gas; (2) size of particles; (3) degree of packing; (4) size of container; (5) shape of particles; (6) size composition of beds of mixed sizes; (7) viscosity of gas; (8) molecular weight of gas and (9) wetting of particles. The temperatures ranged from 25–660° C., the size of particles from 0.01 – 20 centimeters in diameter and the rates from 0.005 – 0.15 liters per second per square centimeter. The character of the surface of the solid particles has a negligible effect, if any, on the resistance to flow. B varied appreciably only with particle size, viscosity and molecular weight of gas. AHE

Metallurgical Limestone. Problems in Production and Utilization. Oliver Bowles. *Bulletin* No. 299, *United States Bureau of Mines*, 1929, 40 pages.

The following subjects on utilization are discussed: (1) blast furnace flux—purpose of flux, action of flux in the furnace, effects of impurities on fluxing stone, slagging effect of magnesia, effect of magnesia on slag viscosity, effect of magnesia on slag utilization, factors governing use of impure fluxing stone, size of stone for blast furnace flux and blast furnace slag; (2) basic open-hearth flux-choice between limestone and lime, effect of impurities in flux, size of flux stone and rate of liquefaction of flux; (3) limestone flux in non-ferrous metallurgy—copper smelting, lead smelting, antimony smelting and brass-foundry fluxes. AHE

The Blast-Furnace Stock Column. S. P. Kinney. *Technical Paper* No. 442, *United States Bureau of Mines*, 1929, 148 pages.

Results are given of a thorough study of the gas velocities, pressures, compositions and temperatures in the interior of a 700-ton blast furnace as determined at planes 3 feet, 11 feet, 21 feet 7 inches and 44 feet 1 inch below the top of the stock column. These show that the flow of gas and stock is far from uniform. The stock flow directly over the tuyères is faster than in the center whereas over the iron notch flow is still greater. The pendulum-like motion of the stock column at the reception of each charge substantiates the belief that the column of stock is partly submerged in and floating on a bath of slag and metal. The high velocity of gas in the center of the plane 3 feet from the top (439 feet per second as compared to 74 feet at the inwall) together with the high velocity at the inwall at each of the 3 lower planes, indicate a loosening of the charge at the inwall due to wall batter. The high velocity at the center of the top is accompanied by high temperature (1350° F.) and gas that contains only 7.4% CO_2. The $CO:CO_2$ ratio in the top gas is 1.69, while there are parts of the furnace where it is 1.29. From the top of the stock column to a point 24 feet above the tuyères, 24.4% of the oxygen in the iron oxide was removed, while 75.6% was removed below this point. About 74% of the carbon charged as coke was burned at the tuyères. The average rate of flow at the stock line was 2.78 inches per minute. Top gas contained about 15% CO_2. AHE

Hearth-Efficiency in Blast-Furnace Practice. W. McConnachie. *Iron & Coal Trades Review*, Dec. 27, 1929, Vol. 119, page 980.

A moderate size blast furnace run with coal produces a quantity of iron with a smaller consumption of carbon than when coke is used. A test made with a group of furnaces smelting a mixture of half Rubio and half Cumberland ore showed that good quality Bessemer iron could be made with 28 cwts. of coal per ton of iron. Figures from these tests show 50.8% of oxygen removed from the ore is unaffected by carbon monoxide when using coal, while with coke only 49% is unaffected. General hearth conditions in a furnace using coal are superior to those of a furnace using coke. RHP

Iron Oxide Reduction Equilibria. A Critique from the Standpoint of the Phase Rule and Thermodynamics. Oliver C. Ralston. *Bulletin* No. 296, *United States Bureau of Mines*, 1929, 326 pages.

The properties of the common oxides of iron, their combinations with each other and their reduction—equilibrium diagrams are presented in this volume. The energy quantities involved are discussed at length. Although there are only 3 authenticated oxides of iron, they dissolve in each other in several series of solid solutions, so that pure oxides are rarely found. Ferric oxide; higher oxides of iron, ferrites and ferrates; the system ferric oxide magnetite; magnetite; iron-oxygen complexes intermediate between magnetite and ferrous oxide; ferrous oxide; iron-oxygen complexes having less oxygen than ferrous oxide; the system iron; the system iron–carbon; other equilibria involving iron carbide; iron carbonyls; the system iron–oxygen; and oxidation–reduction systems for iron oxides are considered in detail. AHE

Book Reviews

Aluminium. Die Leichtmetalle und ihre Legierungen. By P. Melchior. V. D. I. Verlag, Berlin, 1929. Cloth, 280 pages, 6 × $8^1/_4$ inches. Price, 13.50 R. M.

Extraordinary progress has been made in the last decade in the field of light metals, but the knowledge of this was confined to a very small group of specialists. Naturally the aviation industry has placed its hopes in light alloys. The pronounced technical advantages offered to aviation by the light alloys can in a large measure be carried over to other industries, machine, apparatus and conveyance construction. The most important requirement for the advantageous application of the light metals is the extensive knowledge of their properties. For in hardly a single case is it possible to replace the heavy metals without at the same time changing the construction and working of the metals.

At the request of the Deutsche Gesellschaft für Metallkunde an aluminum book was called into being, which first of all will make considerable information available to the engineers and designers, as well as to the operating men.

In the technical publications the scientific data on the properties of light metals take in a wide field. In the aluminum book to make them understood they are given in conjunction with necessary scientific foundations in as brief a form as possible. In addition to pure aluminum, the aluminum casting alloys, the age hardening aluminum alloys (Duraluminum, Lautal, etc.) and the magnesium alloys (Electron) for casting as well as forging are covered. The alloys of light and heavy metals, as aluminum-bronze, etc., are considered.

In addition to the systematic table of contents, a very complete subject index enhances the reference value of the book.

A very evident error appears on page 217. The weight of the duralumin shell of the U. S. Naval Airship is given as 6.4 kg./mm.^{2}; naturally this should read 0.64.—Richard Rimbach.

Principles of Electroplating and Electroforming, By Wm. Blum and G. B. Hogaboom. McGraw-Hill Book Company, Inc., New York, 1930. Cloth 6 × 9 inches, 424 pages. Price, $4.50.

The second edition of this well-known book is a welcome and timely addition to the literature of electrodeposition. The six years since the appearance of the first edition have been marked by an unprecedented development in the industrial applications of plating, an increased activity in research, a greater interest on the part of plant executives and technologists and, of more importance possibly, an awakening on the part of platers generally to the value of research and scientific control. That the second edition so faithfully records the industrial developments and the results of recent research in a manner that executive, chemist and plater alike can understand, is no small tribute to the authors.

The first half of the book consists of a very readable discussion of the methods of expressing conditions of operation, principles of chemistry, chemical analyses, electricity and electrochemistry, followed by chapters on the factors governing the character of the deposits and selection, specification and inspection of electrodeposits, both of which are the most complete discussions of their nature to be found anywhere. Four other chapters on the preparation for electroplating, the preparation for electroforming, electrical equipment, and tanks and their equipment conclude this portion of the book.

The last half of the book is devoted to a discussion of the deposition of copper, nickel, cobalt and iron, chromium, zinc and cadmium, lead and tin, silver, gold and platinum, and lead tin and copper zinc alloys. The chapters on chromium, nickel and brass are exceptionally good, while those on copper, zinc and silver contain much that may also be considered new material for a book on electrodeposition.

The final chapter on experiment in electrodeposition will prove of value as a guide to the increasing number of platers who are already engaged in experimental work, or who have reached that state of development where they are about to undertake such work.

The present volume offers a limited but ample theoretical treatment of the subject, an extended practical presentation and a much more accurate record of available knowledge than the earlier edition. It is a book that all interested in electrodeposition of metals should possess.—A. K. Graham.

Annual Proceedings of the American Society for Testing Materials, Vol. 29 (1929). Two Parts. Part I, 921 pages; Part II, 1016 pages. Price, each part $6.00 in paper, $6.50 in cloth and $8.00 in half-leather.

Vol. 29 (1929) of the annual *Proceedings of the American Society for Testing Materials* has just become available; this volume is issued in two parts.

Part I contains the annual reports of 43 standing and research committees and 5 sectional and joint committees of the Society. They include reports of Committees on Ferrous Metals and Alloys, Effect of Tin and Arsenic on High-Speed Tool Steel, Boiler Feed Water Studies, Non-Ferrous Metals, Cement, Ceramics, Concrete, Fire Tests of Materials, Coal and Coke, Waterproofing Materials, Electrical Insulating Materials, Rubber Products, Textile Materials, Wire Cloth, Slate, Natural Building Stones, Methods of Testing, Metallography and Nomenclature and Definitions; 49 tentative standards which have either been revised or are published for the first time; annual address of the President and the annual Report of the Executive Committee.

Part II contains 56 technical papers with discussion. These contain the symposium on physical properties of cast iron, the symposium on mineral aggregates, and valuable information on the results of investigations by experts in the field of engineering materials including research problems involved in cohesion and atomic structure, the fatigue of metals and corrosion-fatigue of metals. A number of particularly interesting papers on non-ferrous metals are included. These have been abstracted in Metals & Alloys.—H. W. Gillett.

Metallurgy of White Metal Scrap and Residues. By Edmund Thews. D. van Nostrand Company, Inc., New York, 1930. Cloth, 6 × $9^1/_2$ inches. 383 pages, 53 tables. 70 figs. Price, $5.50.

Non-ferrous metallurgists, particularily those in America, directly interested in the metallurgical treatment of white metal scrap and residues, should welcome the debut of a work of this nature. It is complete in scope, comprehensive, and should be indispensable in the hands of the practical metallurgist.

In his introduction, the author emphasizes the growing importance of the scrap and residue industry, and the progress made, in the interest of the elimination of unnecessary waste, toward the simplification and standardization of metallurgical products.

Chapter I is concerned with the smelting of tin and white metal residues such as drosses, skimmings, pure oxides, slags, chemical residues, etc., in the reverberatory and blast furnaces, the the refining of tin and the production of tin-lead alloy. The production of bearing metals, type metals, soft solders, pewter, Britannia metal, fusible alloys and shot is taken up in chapters II to VIII inclusive. Much stress is placed upon the method of production, treatment and composition as determining the suitability of these alloys for their various purposes. Chapter IX describes the methods of melting and refining of white metal scrap. Refining by liquation, sulphurizing, oxidation or steaming, washing, etc., is explained. In chapters X to XIV inclusive, considerable space is devoted to the metallurgical treatment of lead residues in reverberatory and blast furnaces, the importance of correct composition of lead slags, blast furnace coke and the refining of work lead and lead scrap. Chapter XV is concerned with the metallurgical treatment of zinc scrap and ashes. The use of reverberatory furnaces and melting pots for the removal of impurities is presented. The application of crucible, reverberatory and electric furnaces and melting pots to the treatment of aluminum scrap is described in chapter XVI. Reverberatory and crucible furnaces, melting crucibles, design and care of iron and steel melting pots, and refractories for metallurgical furnaces are described in chapters XVII to XXI inclusive. The precipitation and treatment of flue dust and fumes are taken up in chapters XXII and XXIII. These chapters cover the efficiency of various precipitation devices including the "Cottrell" process. The final chapters, XXIV to XXVII inclusive, are concerned with the design of furnace flues or chimneys, methods of sampling the various classes of scrap and residues, and American and German classifications for old metals.

Mistakes are few and of minor importance, and there are several references to other literature. This book should make a host of friends.—Willard O. Cook.

Bismuth, Circular No. 382, Bureau of Standards, by J. G. THOMPSON, Research Associate for the Cerro de Pasco Copper Corporation, 41 pages, 1930, price $0.10, obtainable from Supt. of Documents, Washington, D. C. (stamps not accepted).

The Bureau of Standards (in cooperation with the Cerro de Pasco Copper Corporation) has continued its useful work of summarizing the available data on various metals into "circulars." They might equally well be termed monographs or handbooks. Previous circulars on copper, nickel, nickel steels and light alloys have had wide circulation, and one on zinc and cadmium is in preparation.

The other circulars deal with metals in wide commercial use. The one on bismuth deals with one whose properties are little known to the metallurgist, and which so far has little metallurgical use. Eighty percent of the bismuth used is said to be for medicinal and pharmaceutical uses, and only twenty percent as metal. Much more bismuth could be produced if uses were found for it.

It finds use in "fusible metal," and these may have a large future, (aside from their use in fire alarm and fire control systems) in setting up pieces for various machining, and other mechanical operations. Its alloys serve as gas-tight liquid seals for sealing such apparatus as nitriding ovens, thus substituting for mercury without its cost, or its danger of poisoning where operating temperatures run at least a little above 70° C.

Tempering baths for steel, to operate at low temperatures, may use bismuth alloys, and a list of alloys of Bi, Pb, Sn and Cd (up to 95° C. and without Cd for the higher temperatures) is given with melting points at about 5 degree intervals up to 177° C.

A series of boiler plug alloys with melting points from 100–172° C. is also given.

Bismuth has been used in type metal, though it is not widely so used in this country. Its marked effect upon the surface tension of the alloys to which it is added indicates a possible use in solders. We quote from the circular as follows:

"Outstanding Properties of Bismuth

A review of the literature of bismuth, aside from the pharmaceutical and medicinal literature, indicates that items of outstanding interest are as follows:

Atomic weight.—The atomic weight of bismuth, 209, is the highest of any of the elements which are at all common.

Expansion.—Bismuth is one of the few metals which increase in volume during solidification. This expansion of bismuth amounts to 3.32 percent of its solid volume at the melting point.

Thermal conductivity.—The thermal conductivity of bismuth, 018 calorie per second per cubic centimeter per degree C at 100° C., is less than that of any other metallic element except mercury. The thermal conductivity, already low, is further decreased by exposure to a magnetic field.

Electrical and magnetic properties.—Bismuth is the most diamagnetic of all metals. An alloy of copper, manganese and bismuth is distinctly magnetic although all the components are diamagnetic. Bismuth and antimony are the only metals whose electrical resistance is greater in the solid than in the liquid state. The electrical resistance of solid bismuth is increased by exposure to a magnetic field. Bismuth is one of the seven metals which are abnormal in that their electrical resistance increases with increasing pressure. The resistivity of bismuth is remarkably affected by the presence of small amounts of metallic impurities.

Thermoelectric properties.—Bismuth coupled with silver produces a thermoelectric effect of about 80 microvolts per degree C. This rises to about 120 microvolts per degree C. for bismuth against a bismuth-tin alloy containing 5 to 6 percent tin, and even higher for other combinations such as a bismuth-tin alloy against copper.

Casting properties.—Additions of bismuth lower the surface tension of metals such as lead and tin. Molten alloys which contain bismuth consequently flow freely in a mold and produce sharply defined castings.

Low melting alloys.—Bismuth is notable for its ability to lower the melting points of many metallic alloys. Several alloys which contain bismuth melt as temperatures lower than that of boiling water. In contrast to these low melting points is the fact that some metallic compounds of bismuth, particularly with alkali metals and with cerium, have surprisingly high melting points."

The circular brings together the data on the fundamental properties of the metal, shows 25 binary and ternary equilibrium diagrams and contains 242 references to the literature.

The Bureau of Standards' work on the compilation of data into circulars, unlike its other work, is not published in the Bureau's Journal of Research, so to make sure that one has the circulars in his library, he must put in a special order for them. They are probably more used, and more useful, than the bulk of the reports of laboratory investigations. This one is no exception and when one wants information on bismuth, the use of this circular will save much time in hunting through the literature.—H. W. G.

Reviews of Manufacturers' Literature

In this department we shall list each month a selection of the catalogs, books, treatises and other printed matter issued by manufacturers which, in our judgment should be of interest to the readers of METALS & ALLOYS. *Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter for consideration by the editor of this department are invited to do so, and it is suggested that* METALS & ALLOYS *be placed on the regular mailing list so that advance copies of any material of interest to the metallurgical field may automatically come to this department*—EDITOR.

Purite.—This 12-page booklet, the first of a series of 3, gives a non-technical discussion of the development of Purite, and its chemical properties in the relation to cast iron and steel. The chemical reactions involved in the addition of fused soda ash to molten iron are described in a thoroughly scientific manner by George S. Evans, Metallurgist, Mathieson Alkali Company, 250 Park Avenue, New York, N. Y.

Nickel Cast Iron.—Number 1 of an attractively printed 8-page miniature newspaper telling about numerous applications of nickel cast iron in the automotive, railway, marine, refrigeration and other industries. The International Nickel Company, Inc., 67 Wall Street, New York, N. Y.

Pyrometers for Type Metal.—A four-page pamphlet describing the "Alnor" portable and stationary temperature measuring instruments for newspapers, publishers, electro-typers, type founders, etc. These instruments are also applicable to other metals such as babbit, lead, solder, white metal or any alloys which are poured or cast at low temperature. Illinois Testing Laboratories, Inc., 141 W. Austin Avenue, Chicago, Ill.

Dilatometers.—Catalog D-1, a 14-page illustrated pamphlet describing the Chevenard equipment for thermal studies of steel, alloys, refractories, glass, etc. The laboratory at the Steel Works at Imphy, France, has long been a center of studies of a purely scientific nature while serving also as a guide and check-up on the mills. Invar, elinvar, fixinvar, and other special alloys are the result of the researches of Dr. Charles Eduard Guillaume, Director of the International Bureau of Weights and Measures, which have been carried on in connection with this laboratory. For thirty years this laboratory has been building up an enviable reputation. The present catalog deals with apparatus devised by Pierre Chevenard of this laboratory, a mining engineer and professor at the École Nationale Superieure des Mines at St. Etienne, who has made a well-known series of researches at this laboratory. The R. Y. Ferner Co., Investment Bldg., Washington, D. C.

Arc Welding.—A profusely illustrated 39-page booklet entitled "Arc Welding in Industry" describing the various industrial applications of arc welding, and the G. E. equipment offered for that purpose. General Electric Company, Schenectady, N. Y.

Foundry Equipment.—A new book illustrating and describing recent installations of Link-Belt Foundry Equipment for the preparation and handling of sand, molds and castings. This book, No. 1090, illustrates and describes the most recent practice in modern foundries, and pictures actual installations in many types of foundries throughout the country. Other recently issued books of interest to Foundrymen are: No. 1120, Link-Belt Vibrating Screen—the ideal sand reclaiming and shake-out unit; No. 1118, describing the Saginaw Malleable Foundry; and No. 1119, covering the American Manganese Steel Company foundries. Link-Belt Company, 910 S. Michigan Ave., Chicago, Ill.

Safety Advertising.—Industrial Safety, Number 6, is a 6-page booklet outlining methods of preparing and displaying safety advertising material as a means of keeping employees constantly informed of the importance of safe workmanship. Policyholders Service Bureau, Metropolitan Life Insurance Company, New York, N. Y

Haystellite.—A 32-page booklet describing the application to oil-well drilling tools of a cast tungsten carbide called Haystellite, of the cobalt chromium tungsten alloy Haynes Stellite, and of the chromium manganese iron welding rod, Hascrome used for applying the tungsten carbide or as a bond between the metal of the tool and stellite. Haynes Stellite Co., Kokomo, Ind.

Graphic Time Recorders.—Bulletin 330 gives a full description of the Esterline-Angus time recorder, as well as illustrations of several applications. Esterline-Angus Company, Speedway Ave., Indianapolis, Ind.

Non-Ferrous Alloys and Products.—Twenty-four page booklet gives information on various non-ferrous alloys: physical properties, corrosion resistance, machining, analysis, etc. Hills-McCanna Company, 2349 Nelson Street, Chicago, Ill.

Graphic Instruments.—Bulletin No. 830 announces a new line of graphic instruments for alternating and direct current, supplied in switchboard, wall and portable types. Roller-Smith Company, 233 Broadway, New York, N. Y.

Electric Furnaces.—A 4-page illustrated pamphlet describing the New Bellis Electric Furnace for annealing operations on ferrous or non-ferrous metals including detailed information as to the operating advantages claimed for these furnaces. The Bellis Heat Treating Co., Branford, Conn.

Hytempite in the Foundry.—A 12-page illustrated pamphlet giving detailed information as to various useful applications of Hytempite in iron steel and brass foundries. Quigley Furnace Specialties Company, Inc., 56 West 45th Street, New York, N. Y.

Catalog No. 1094.—This publication devotes itself to the development of the "Guthrie-Leitz" Grinding and Polishing Machine. The history of metallography reveals the preparation of samples as a long and tedious as well as an unsatisfactory process in which the human equation and skill plays a most important part. The "Guthrie-Leitz" Grinding and Polishing Machine overcomes these defects. It is designed to operate in a most efficient manner, reducing the human equation to a negligible factor. It is, therefore, now entirely possible for the "Guthrie-Leitz" Grinding and Polishing Machine to prepare a number of specimens at one time and to entrust the preparation of the samples to an operator who is less experienced than is necessary with any other equipment. The instrument is entirely automatic and by using a magnetic specimen holder, the individual specimens are polished in a most satisfactory manner. E. Leitz, Inc., 60 East 10th St., New York, N. Y.

Steel Stamina.—The January-February issue of this house organ is devoted to a description of the new Lindberg plant in full operation, the equipment of the heat treating plant and the laboratory is illustrated. This issue also contains a number of hints for the tool hardener. Lindberg Steel Treating Co., 216 Union Park Court, Chicago, Ill.

Patent Department

Through an arrangement with Mr. W. M. Corse, Metallurgical Engineer, Washington, D. C., who operates a well-known Patent Information Service, we are able to publish every month a list of important patents in the metallurgical field from the United States, Canada and Europe. The following countries will be included in the European listing: England, Germany, France, Switzerland, Denmark, Norway, Sweden and Italy.

If our readers wish more information about any of the patents listed below they can get it by writing to our Patent Department, and mentioning the fact that they have seen the reference in METALS & ALLOYS. *We will be prepared to mail copies of United States Patents to clients within twenty-four hours of date of issue by special arrangement. Photostatic copies, translations of claims and of full text of foreign patents will be supplied if desired.*

This service is furnished under special arrangement with Mr. Corse's organization at most reasonable rates. Full information can be secured by writing to Patent Department, METALS & ALLOYS, *419 Fourth Avenue, New York.*

United States Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Means for soldering contact points. M. M. Austin, Waukegan, and L. J. Warner, assignors to Fansteel Products Co., Inc., both of North Chicago, Ill. No. 1,748,938. June 27, 1928.

Ingot-pushing device. J. Gassen, assignor to Schloemann Akt-Ges., both of Düsseldorf, Germany. No. 1,748,948. July 27, 1928.

Process for treating siliceous minerals. A. J. Moxham, Odessa, Del., assignor to Electro Co. No. 1,748,989. Nov. 25, 1924.

Means for separating adhering rolled metal sheets. E. Hinderer, Hamborn, Germany, assigner to Vereinigte Stahlwerke Akt.-Ges., Düsseldorf, Germany. No. 1,749,075. Jan. 7, 1927.

Apparatus for pouring liquids such as molten metals. A. W. Morris, Drexel Hill, and S. P. Wetherill, Jr., Haverford, Pa., assignors to Wetherill-Morris Engineering Co., Philadelphia, Pa., No. 1,749,083. March 18, 1929.

Two-step sulphatizing roast. F. A. Brinker, San Francisco, California., assignor of one-fourth to J. R. Ruth of Denver, Colo. No. 1,740,125. Oct. 21, 1926.

Reducing zinciferous materials. E. H. Bunce and G. T. Mahler, Palmerton, Pa., assignors to The New Jersey Zinc Company, New York, N. Y., No. 1,749,126. Jan. 4, 1928.

Reducing zinciferous materials containing lead. E. H. Bunce and G. T. Mahler, Palmerton, Pa., assignors to The New Jersey Zinc Company, New York, N. Y. No. 1,749,127. Jan. 4, 1928.

Arc welding system. R. E. Frickey, San Francisco, and A. S. Kalenborn Redwood City, Calif. No. 1,749,133. Nov. 29, 1924.

Sheet metal heating furnace. W. A. Lacke, Chicago, Ill. No. 1,749,143. Nov. 29, 1922.

Process of piston-ring casting. T. E. McFall, Sparta, Mich. No. 1,749,147. March 5, 1929.

Process of flanging sheet metal. J. A. McGregor, Cleveland, Ohio. No. 1,749,148. March 7, 1928.

Apparatus for forming flanged openings in sheet-metal panels and the like. R. E. Hansen, Detroit, and O. J. Groehn, Grosse Pointe Park, Mich., assignors to Hudson Motor Car Co., Detroit, Mich. No. 1,749,184. Dec. 17, 1927.

Utilization of dolomite or magnesium limestone for production of metallic magnesium, etc. H. H. Dow and E. O. Barstow, assignors to the Dow Chemical Co., all of Midland, Mich. No. 1,749,210. Oct. 30, 1926.

Production of metallic magnesium, etc., from dolomite or magnesium limestone. H. H. Dow and E. O. Barstow, assignors to The Dow Chemical Co., all of Midland, Mich. No. 1,749,211. Nov. 8, 1926.

Casting apparatus. S. H. Carbis, Tarentum, Pa. No. 1,749,314. Jan. 27, 1928.

Forging machine and the like. O. Georg, Düsseldorf, Germany. No. 1,749,334. Sept. 30, 1926.

Method and machine for forming, bending and cutting off metal strips. M. Hazen, Cincinnati, Ohio. No. 1,749,342. May 25, 1927.

Apparatus for forming radiators. J. Karmazin, Detroit, Mich. No. 1,749,383. Oct. 12, 1927.

Soldering iron. J. F. Schylander, Chicago, Ill. No. 1,749,396. Oct. 19, 1927.

Rotary shears. L. Iversen, Pittsburgh, Pa. No. 1,749,430. April 3, 1926.

Roll-table. L. Johnson, Ingram, Pa., assignor to United Engineering and Foundry Co., Pittsburgh, Pa. No. 1,749,431. Jan. 20, 1927.

Electrodeposition of chromium. C. H. Proctor, Arlington, N. J., assignor to The Roessler & Hasslacher Chemical Co., N. Y. No. 1,749,443. March 9, 1929

Drying sand molds. R. Sculthorpe, assignor to Shenango-Penn Mold Co. both of Sharpsville, Pa. No. 1,749,448. Nov. 17, 1928.

Mold pattern. F. W. Tickner, Sharon, and J. Thomas, Sharpsville, Pa., assignor to Shenango-Penn Mold Co., Sharpsville, Pa. No. 1,749,454. Feb. 4, 1929.

Soldering device. J. F. Schylander, Chicago, Ill. No. 1,749,512. Nov. 30, 1925.

Compound for filling recesses in metal castings and the like. Z. M. Marr, Fremont, Nebr. No. 1,749,541. April 16, 1928.

Bending device. M. W. Walkup, Chicago, Ill. No. 1,749,616. Aug. 26, 1927.

Process for rolling metal. W. T. Miller, Bethlehem, Pa., assignor to Bethlehem Steel Co. No. 1,749,671. Feb. 11, 1925.

Manufacture of alloy steels. A. D. Shankland, Bethlehem, Pa., assignor to Bethlehem Steel Co. No. 1,749,678. May 19, 1926.

Electric soldering machine. D. K. Wright, Paterson, N. J., assignor to General Electric Co. No. 1,749,684. Mar. 28, 1925.

Apparatus for the continuous treatment of metal bodies. M. Fourment, Paris, France. No. 1,749,700. Dec. 22, 1926.

Process for autogenous welding of magnesium and its alloys. G. Michel, Bagneux, France, assignor to H. O. Berg, Paris, France. No. 1,749,712. Feb. 5, 1925.

Process for the protection of readily-oxidizable metals. G. Michel, Bagneux, France, assignor to H. O. Berg, Paris, France. No. 1,749,713. Aug. 13, 1925.

Electric soldering machine. C. Reiter, Berlin-Treptow, and M. Stager, Berlin-Baumschulenweg, Germany, assignors to General Electric Co. No. 1,749,719. Dec. 5, 1923.

Ingot stripper. R. H. Stevens, Westmont Borough, Pa., assignor to Bethlehem Steel Co. No. 1,749,723. Aug. 23, 1928.

Tunnel kiln and method of operating same. F. A. J. Fitz Gerald, Niagara Falls, N. Y., and J. Kelleher, Chippawa, Ont., assignors to Harper Electric Furnace Corp. No. 1,749,762. June 10, 1925.

Apparatus for electric welding. J. B. Hendrickson, Philadelphia, Pa., assignor to Welding Engineers, Inc. No. 1,749,765. Mar. 13, 1926.

Rolling-mill-driving system. J. Ledwinka, assignor to Budd Wheel Co., both of Philadelphia, Pa. No. 1,749,883. Nov. 20, 1926.

Method and apparatus for shaping sheet-metal articles. O. J. Groehn, Grosse Pointe Park, Mich., assignor to Hudson Motor Car Co., Detroit, Mich. No. 1,749,913. Dec. 10, 1927.

Method of welding wheel parts. J. W. Meadowcroft, assignor to Budd Wheel Co., both of Philadelphia, Pa. No. 1,749,917. Mar. 21, 1928.

Hanger for articles to be plated. L. Lichtman, assignor to Chromeplate, Inc., both of New York, N. Y. No. 1,749,952. Nov. 27, 1928.

Rack or hanger for articles to be plated. L. Lichtman, assignor to Chromeplate, Inc., both of New York, N. Y. No. 1,749,953. Nov. 27, 1928.

Method of making welded joints for steel pipe. F. C. King, Portland, Ore. No. 1,750,010. Nov. 11, 1926.

Welding machine. H. D. Randall, assignor to Randall Co., both of Cincinnati, Ohio. No. 1,750,050. June 22, 1927.

Electroplating process. R. B. P. Crawford, Chicago, Ill., and R. D. Synder, Hazleton, Pa. No. 1,750,092. Jan. 23, 1930.

Link-welding machine. H. Weinacker, assignor to Universal Chain Co., both of Maplewood, N. J. No. 1,750,142. Aug. 6, 1927.

Thermit mixture. J. H. Deppeler, Weehawken, N. J. No. 1,750,162, Sept. 8, 1928.

Molding apparatus. B. L. Elwell, Granite City, Ill. No. 1,750,217. April 2, 1929.

Coated iron and steel articles and method of making same. E. M. Jones, assignor to Parker Rust-Proof Co., both of Detroit, Mich. No. 1,750,270. June 13, 1927.

Sizing die for flange bearings. A. H. Valentine and J. C. Lemming, assignors to The Moraine Products Co., all of Dayton, Ohio. No. 1,750, 290. Jan. 6, 1928.

Welding flux. R. R. Fulton, Wilkinsburg, Pa., assignor to Westinghouse Electric and Mfg. Co. No. 1,750,301. Sept. 16, 1926.

Soldering apparatus. R. J. Emmert, Anderson, Ind., assignor, by means assignments, to Delco-Remy Corporation, Dayton, Ohio. No. 1,750, 312. April 29, 1925.

Deep-metal refiner. W. M. Conner, assignor to American Tin Co., Inc., both of Baltimore, Md. No. 1,750,390. Feb. 12, 1929.

Etching and decorating metal surfaces. J. C. McFarland, Ft. Thomas, Ky., assignor to The Wadsworth Watch Case Co., Dayton, Ky. No. 1,750,418. Dec. 5, 1928.

Electric-arc cutting apparatus. V. B. Sounitza, Pasadena, Calif. No. 1,750,436. Jan. 23, 1930.

Electrical welding machine. R. T. Todd, Warren, Ohio, assignor to The Taylor Winfield Corp. No. 1,750,442. June 9, 1928.

Rolling mill for tapered disks. A. Martin, Pittsburgh, Pa., assignor to Budd Wheel Co., Philadelphia, Pa. No. 1,750,480. Oct. 13, 1921.

Process of drying, cleaning and polishing sheet metal with corncob materials. C. C. Truax, Toledo, Ohio. No. 1,750,498. Sept. 22, 1926.

Method of treating articles in tumbling barrels. C. C. Truax, Toledo, Ohio. No. 1,750,499. Oct. 9, 1926.

Sheet-making apparatus. A. R. McArthur, Gary, Ind., assignor to American Sheet & Tin Plate Co., Pittsburgh, Pa. No. 1,750,534. March 21, 1928.

Welding copper and the like. T. E. Murray, Jr., and I. T. Bennett, said Bennett assignor to T. E. Murray, both of Brooklyn, N. Y. No. 1,750,643. July 5, 1927.

Means of cleaning and protecting metal surfaces. J. C. Vignos, Nitro, W. Va., assignor to The Rubber Service Laboratories Company, Akron Ohio. No. 1,750,651. Nov. 19, 1927.

Alloy block for soldering. F. W. Koch, Oakland, Calif. No. 1,750,671. Nov. 20, 1928.

Alloy (Al-Cd-etc.). P. Berthelemy and H. de Montby, Paris, France. No. 1,750,700. August 9, 1927.

Ingot-mold flask. V. Tope, Sharpsville, Pa. No. 1,750,734. Feb. 25, 1929.

Aluminum alloy (Containing carbon). A. Geyer, Paris, France. No. 1,750,751. Feb. 4, 1927.

Electric welding machine. F. H. Johnson, Detroit, Mich. No. 1,750, 757. May 19, 1927.

Method of inhibiting corrosive effect of brines toward iron and steel. O. V. Martin, Sand Spring, Okla., assignor to The Martin-Colvin Co. No. 1,750,761. Oct. 26, 1927.

Twisting non-circular blanks for drills, etc. F. T. Harrington, assignor to Whitman & Barnes, Inc., both of Detroit, Mich. No. 1,750,776. Apr. 25, 1928.

Alloy and cutting tool made therefrom (W-Co-Cr-B). B. E. Field, Douglaston, N. Y., assignor to Haynes Stellite Co. No. 1,750,796. Aug. 29, 1925.

Hanger for articles to be plated. L. Lichtman, assignor to Chromeplate, Inc., both of New York, N. Y. No. 1,750,807. Nov. 27, 1928.

Rack for supporting articles to be electroplated. L. Lichtman, assignor to Chromeplate, Inc., both of New York N. Y. No, 1,750,808. Nov. 27, 1928.

Art of making metal fabrics. E. B. Cairns, New York, N. Y., assignor to Cairns Development Co., Wilmington, Del. No. 1,750,831. Mar. 5, 1927.

Heat-treating machine. W. A. Darrah, Chicago, Ill. No. 1,750,924. June 4,1927.

Apparatus for jointing lead or like pipes or sheaths. A. E. Wilson, Bromley, England. No. 1,751,019. Sept. 10, 1927.

Casting magnesium and alloys thereof. J. E. Hoy, assignor to The Dow Chemical Company, both of Midland, Mich. No. 1,751,038. July 3, 1926.

Automatic welding. W. H. D'Ardenne, J. O. Landis and L. H. Christensen, assignors to Heintz Mfg. Co., all of Philadelphia, Pa. No. 1,751,077. Dec. 30, 1927.

Process for producing metals in electric furnaces. E. G. T. Gustafsson, Stockholm, Sweden. No. 1,751,083. May 11, 1927.

Method of and apparatus for forming heads on tubular articles. R. K. Hopkins, New York, N. Y., assignor to The M. W. Kellogg Co. No. 1,751,085. Sept. 29, 1927.

Wire-straightening machine. G. F. Matteson, Rockyhill, Conn., assignor to The F. B. Shuster Co., New Haven, Conn. No. 1,751,094. Apr. 6, 1928.

Process of making electrolytic iron from scrap. No. 1,751,099. R. D. Pike, Piedmont, Calif. July 20, 1926.

Traversing-roll mounting. J. W. Smith, assignor to Budd Wheel Co., both of Philadelphia, Pa. No. 1,751,108. Jan. 29, 1926.

Apparatus for heating the air blast for furnaces and the like. J. P. Dovel, Birmingham, Ala. No. 1,751,136. Dec. 16, 1926.

Multiple hearth furnace. E. J. Fowler, deceased, Redwood City, Calif., by E. M. Fowler, executrix, Redwood City, Calif. and D. Baird, Berkeley, Calif , assignors to Nichols Copper Co., New York, N. Y. No. 1,751,142. Mar. 8, 1928.

Process in the manufacture of self-baking electrodes. M. O. Sem, Buffalo, N. Y , and C. W. Söderberg, Oslo, Norway, assignors to Det Norske Aktieselskab for Elektrokemisk Industri of Norway, Oslo, Norway No. 1,751,177. Dec 6, 1928.

Smelting process (low-carbon cast iron). F. Wüst, Düsseldorf, Germany. No. 1,751,185. Oct. 18, 1927.

Auxiliary jet cutting tip for cutting torches. C. J. Coberly, assignor to Kobe, Inc., both of Los Angeles, Calif. No. 1,751,191. Sept. 29, 1923.

Insulating coating on aluminum or aluminum alloys. L. McCulloch, Pittsburgh, Pa., assignor to Westinghouse Electric & Mfg. Co. No. 1,751,213. Nov. 19, 1927.

Composition and manufacture of refractory basic brick and the like. C. S. Garnett, Derby, England. No. 1,751,234. Mar. 6, 1923.

Apparatus and process for tempering steel. A. O. Dennis, Springfield, Ohio. assignor to The Central Brass & Fixture Company, Dayton, Ohio. No. 1,751,269. Apr. 20, 1928.

Electric furnace. W. Keenan, Schenectady, N. Y., assignor to General Electric Co. No. 1,751,334. Dec. 27, 1924.

Process of mounting the dies used as in production of metal threads or wires. C. Archer, Meximieux, France. No. 1,751,382. Jan. 13, 1928.

Blowpipe. J. Harris, Cleveland, Ohio, assignor to The Harris Calorific Co., Cleveland, Ohio. No. 1,751,402. Sept. 12, 1925.

Electric furnace. C. L. Ipsen, Schenectady, N. Y., assignor to General Electric Co. No. 1,751,408. Oct. 23, 1924.

Adapter for blowpipes. L. Campbell, Jr., assignor to The Harris Calorific Co., Cleveland, Ohio. No. 1,751,447. Dec. 30, 1926.

Blowpipe tip and process of making same. L. Campbell, Jr., Lakewood, Ohio, assignor to The Harris Calorific Co., Cleveland, Ohio. No. 1,751,448. June 20, 1928.

Hard-metal alloy and the process of making same (Tungsten carbide). K. Schröter, Berlin-Lichtenberg, Germany, assignor to General Electric Co. Reissue Patent No. 17,624. (Original No. 1,549,615, filed Aug. 11, 1925) July 22, 1929.

Tamping device for use in molding operations. F. Breeden, assignor to Automatic Moulding Machines, Ltd., both of Birmingham, England. No. 1,751,465. March 21, 1929.

Method of forming articles from heat-treatable aluminum base alloys. R. S. Archer, Cleveland, Ohio, assignor to Aluminum Co. of America, Pittsburgh, Pa. No. 1,751,468. Dec. 24, 1927.

Core-forming apparatus. T. H. Brown, Lansdowne Borough, Pa., assignor, by mesne assignments, to National Sash Weight Corp., Baltimore, Md. No. 1,751,470. Oct. 26, 1926.

Core and process of forming the same. E. L. Leasman, Milwaukee, Wis. No. 1,751,482. June 20, 1927.

Method of making bimetallic strips for thermostats. F. W. Miller, Hockley Heath, England. No. 1,751,489. April 6, 1927.

Method of forming articles from heat-treatable aluminum-base alloys. W. C. Winter, Parnassus, Pa., assignor to Aluminum Co. of America, Pittsburgh, Pa. No. 1,751,500. Dec. 13, 1927.

Electric soldering machine. J. Cunningham, Riverton, N. J., assignor, by mesne assignments, to American Telephone and Telegraph Co. No. 1,751,509. Mar. 30, 1927.

Method and apparatus for making joints. J. Cunningham, Riverton, N. J., assignor, by mesne assignments, to American Telephone and Telegraph Co. No. 1,751,510. Aug. 9, 1928.

Process of preparing alumino-thermic mixture. R. W. Hyde, Summit, N. J. No. 1,751,550. Sept. 29, 1928.

Anode and method of making same (nickel anode). W. J. Harshaw, Shaker Heights, P. M. Savage, Elyria and F. K. Bezzenberger, Cleveland Heights, Ohio, assignor, by mesne assignments, to The International Nickel Co., Inc., N. Y. No. 1,751,630. Nov. 28, 1927.

Arc welding. M. R. Taylor, E. Cleveland, Ohio, assignor to The Lincoln Electric Co., Cleveland, Ohio. No. 1,751,668. April 18, 1927.

Removable furnace roof. L. S. Abbott, Chicago, Ill. No. 1,751,675. March 17, 1927.

Car loading and unloading method (Packs of sheet metal). R. T. Romine, Mount Clemens, Mich. No. 1,751,717. Aug. 10, 1926.

Cast-iron mold. J. L. Dostal, assignor to E. Holley, both of Detroit, Mich. No. 1,751,727. Sept. 12, 1927.

Apparatus for reducing oxides of metals. J. W. Hornsey, Oakes-in-Norton, by Sheffield, Eng., assignor to Granular Iron Co. No. 1,751,736. Sept. 8, 1926.

Method of making turbine blades. J. L. Ray, Swarthmore, Pa., assignor to Westinghouse Electric & Manufacturing Co. No. 1,751,758. Aug. 1, 1928.

Casting Machine. J. W. Smith, Cleveland, Ohio. No. 1,751,766. Dec. 3, 1928.

Method for making zinc from oxygen compounds of zinc or substances containing oxygen compounds of zinc. C. F. von Girsewald and H. Neumark, Frankfurt a. M., Germany. No. 1,751,778. Oct. 12, 1928.

Austrian Patents

Subject of Invention, Patentee, Patent No. and Date Term of Patent Began.

Process for working up mixed chips of white and red metal. Internationale Metall A.-G., Vaduz, Liechtenstein, assignee of A. Schwarz, Wien, Austria. No. 116,479. Nov. 15, 1928.

Electrode seal for electric furnaces. Siemens & Halske A.-G., Berlin, Germany and Wien, Austria., assignee of A. Rönsch, Charlottenburg, Germany. No. 116,524. June 15, 1928.

Process for chromium plating other metals. R. Appel, Berlin, Germany. No. 116,355. Sept. 15, 1929.

Process for electrolytically renewing the copper-covered surfaces of the printing rolls or cylinders of printing presses and the like. H. Kuppel, Clichy, France, and L. Siméant, Paris, France. No. 116,525. Sept. 15, 1929.

Process for making silver-plated tableware having reinforcing plates. Bremer Silberwarenfabrik Akt.-Ges., Sebaldsbrück, near Bremen, Germany. No. 116,332. Sept. 15, 1929.

Process for drawing tubes. Enzefelder Metallwerke A.-G., Enzefeld, North Austria. No. 116,532. Aug. 15, 1926.

Process for briquetting ore fines, blast furnace dust and the like. P. Jung, Neuköln, Germany. No. 116,708. Oct. 15, 1929.

Electric annealing furnace. Siemens Schuckertwerke G.m.b.H., Berlin-Siemensstadt, Germany. No. 116,709. Oct. 15, 1929.

Process and device for casting molten metal under pressure. R. H. V. Christensen, Copenhagen, Denmark. No. 116,750. Oct. 15, 1929.

Nickel-tungsten steel. M. Baeke, Berlin, Germany. No. 116,860. July 15, 1928.

Rolling mill having backed working rolls. A. Kriwan, Mährisch-Ostrau-Privoz, Upper Silesia, Germany. No. 117,276. June 15, 1928.

Process for the production of calcium carbide or ferrosilicon. Gebrüder Siemens & Co., Berlin-Lichtenberg, Germany. No. 117,081. Nov. 15, 1929.

Process, apparatus and molds for making zinc cups for galavanic elements, batteries and the like. A. Gassan, Berlin-Frohnau, and P. Ruck, Berlin, Germany. No. 117,103. Nov. 15, 1929.

Process and device for introducing air into the roasting chambers of mechanical muffle roasting furnaces. "Balz-Erzröstung" G.m.b.H., Gleiwitz, Germany. No. 117,022. Nov. 15, 1929.

Magnetic copper-iron-nickel alloy. W. S. Smith, Benchams, and H. J. Garnett, Lymne, England. No. 117,015. Nov. 15, 1929.

Accessory for baths for treating objects, particularly electrolytic baths. Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. No. 117,024. Nov. 15, 1929.

Process for coating metal with lead containing tin. American Machine & Foundry Co., New York, N. Y. No. 117,012. Nov. 15, 1929.

Metal foil. American Machine & Foundry Co., New York, N. Y. No. 117,032. Nov. 15, 1929.

Process for welding with the carbon arc. "Elin" Akt.-Ges für elektrische Industrie, Wien, Austria. No. 117,001. Nov. 15, 1929.

Process for welding broken parts of machinery and the like. Cetto & Co., G.m.b.H., Düsseldorf, Germany. No. 117,253. Nov. 15, 1929.

Method of and machine for straightening sheets. F. Ungerer, Pforzheim, Germany. No. 116,994. Nov. 15, 1929.

British Patents

(Names of communicants appear in parentheses)

Subject of Invention, Patentee, Patent No. and Filing Date.

Deforming a crystalline aluminum body. S. G. S. Dicker (Naamlooze Vennootschap Philips' Gloeilampenfabrieken). No. 324,900. Aug. 1, 1928.

Smelting ores to metal, matte and slag. H. Skappel. No. 324,902. Aug. 3, 1928.

Welding-torches. British Thomson-Houston Co., Ltd. No. 297,032. Sept. 12, 1927.

Hard metal compositions. British Thomson-Houston Co., Ltd. No. 303,751. Jan. 7, 1928.

Elimination of the iron contained in bauxites or other aluminous ores. U. B. Voisin. No. 306,094. Feb. 15, 1928.

Alloys. C. Phillippossian. No. 325,131. Nov. 3, 1928.

Electric arcs for welding and like purposes. Presslicht-Patent-Verwertungsges., and E. Wist. No. 325,132. Mar. 5, 1929.

Presses for working sheet metal and the like. H. D. Fitzpatrick (Marquette Tool & Manufacturing Co.). No. 325,139. March 12, 1929.

Rendering suitable for re-use sulphuric acid used for treatment of ores of titanium containing chromium. Deutsche Gasglühlicht-Auer-Ges. No. 309,597. April 14, 1928.

Manufacture of hollow metal rods, bars and the like. A. P. Pehrson and F. Lloyd. No. 325,169. April 29, 1929.

Continuous process and furnace for the thermal treatment of metals and other substances. Infra. No. 306,446. Feb. 20, 1928.

Conveyors for furnaces. International Nickel Co. No. 315,344. July 12, 1928.

Ingot molds. G. W. Naylor, J. F. Naylor, W. Naylor and C. E. Naylor. No. 325,303. Nov. 22, 1928.

Treatment of steel castings or other metals. G. Herrmann and L. Zerzog. No. 325,307. Nov. 26, 1928.

Mechanism for feeding electrodes in automatic or semi-automatic arc welding machines. British Thomson-Houston Co., Ltd. No. 301,434. Nov. 29, 1927.

Heat-resisting alloy. Oesterreichische Schmidtstahlwerke Akt.-Ges. No. 305,047. Jan. 28, 1928.

Oxyacetylene or like burners. H. Wade (Soc. L'Air Liquide, Soc. Anon. pour l'Etude et l'Exploitation des Procédés G. Claude). No. 325,380. Feb. 8, 1929.

Machine for spinning articles of metal and alloys. P. C. Christiansen. No. 307,035. March 1, 1928.

Method and device for roasting and agglomerating fine ore or roasting residues. Soc. pour l'Enrichissement et l'Agglomeration des Minerais. No. 307,708. March 10, 1928.

Multiple metals and methods of manufacturing the same. International General Electric Co. No. 308,819. March 31, 1928.

Rolled-metal bars and means for their production. F. R. Simpson & Co., Ltd. and J. W. D. Melhuish. No. 325,436. May 14, 1929.

Foundry moulding machines. British Insulated Cables, Ltd., and F. W. Bullock. No. 325,453. June 20, 1929.

Preparation of blende for sintering. Soc. Anon. La Nouvelle Montagne. No. 325,455. Jan. 5, 1929.

Drawing zinc shells. W. Erfurth. No. 314,878. July 3, 1928.

Molds for casting metals. A. E. White (Aluminium, Ltd.). No. 325,553. Aug. 21, 1928.

Welding-machines. Svenska Aktiebolaget Gas-Accumulator. No. 314,063. June 22, 1928.

Casting rain-water gutters. Anderston Foundry Co., Ltd., and T. P. Cargill. No. 326,121. July 19, 1929.

Producing blade rings for radial-flow steam or gas turbines and blade rings produced by this method. Ljungströms Ångturbin Aktiebolaget. No. 319,323. Sept. 20, 1928.

Magnetic alloys and methods of making the same. British Thomson-Houston Co., Ltd. No. 314,971. July 6, 1928.

Electric welding-burner. W. W. Triggs (Elin Akt.-Ges. für Elektrische Industrie). No. 301,470. Nov. 29, 1928.

Furnaces for de-tinning metal plates and other articles or surfaces coated with block tin or other like material. Leeds De-Tinning, Ltd., and A. W. Calvert. No. 326,237. Dec. 8, 1928.

Decorating metal. J. de Frene. No. 326,257. Dec. 13, 1928.

Refractory materials. Carborundum Co., Ltd. (Carborundum Co.) No. 326,279. Jan. 1, 1929.

Cementing and hardening iron, iron alloys and steel. Deutsche Gold-und Silverscheideanstalt Vorm.-Roessler. No. 304,209. Jan. 16, 1928.

Cementing and hardening iron, iron alloys and steel. Deutsche Gold-und Silverscheideanstalt Vorm.-Roessler. No. 308,963. Apr. 2, 1928.

Process of and apparatus for welding dental pieces. M. Charlier. No. 308,581. March 24, 1928.

Electric furnaces. T. D. Kelly and G. E. Leavey. No. 326,321. Feb. 22, 1929.

Moulders' ramming-machines. A. E. White (Landon Radiator Co. Inc.) No. 326,340. March 4, 1929.

Presses for stamping sheet metal and the like. Huntley, Boorne & Stevens, Ltd., and W. L. Brown. No. 326,380. Apr. 11, 1929.

Electric Furnaces. P. L. J. Miguet and M. P. Perron. No. 313,121. June 7, 1928.

Process of treating ores. A Folliett and N. Sainderichin. No. 312,667 May 30, 1928.

Canadian Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Alloy for telegraphic and telephonic conductors. W. S. Smith, Newton Poppleford, Devonshire; H. J. Garnett, Sevenoaks, Kent; and J. A. Holden, Gidea Park, Essex, England. No. 297,673. Nov. 16, 1927.

Refinement of nickel alloys. W. S. Smith, Newton Poppleford, Devonshire, H. J. Garnett, Sevenoaks, Kent; and J. A. Holden, Gidea Park, Essex; England. No. 297,674. May 5, 1928.

Method of treating materials with binders and briquetting them. R. Lessing, London, England. No. 297,720. Oct. 7, 1927.

Process of extracting platinum from ores. J. W. Mellor, Stoke-on-Trent, Staffordshire, England. No. 297,724. Nov. 5, 1927.

Machine for manufacturing nails from wire. J. Wikschtröm, Düsseldorf, Germany. No. 297,754. Dec. 22, 1928.

Process for making X-ray anodes. The Canadian General Electric Co., Ltd., Toronto, Ont., assignee of E. G. Gilson, Colonie, N. Y. No. 297,775. July 19, 1928.

Control system for rolling mills. The Canadian Westinghouse Co., Ltd., Hamilton, Ont., assignee of H. C. Jenks, Wilkinsburg, Pa. No. 297,780. Dec. 24, 1928.

Heat treating apparatus for metals, etc. C. F. Hammond and W. Schackleton, both of London, England. No. 297,877. Aug. 10, 1928.

Gold-saving apparatus. G. L. Covington, Chehalis, Wash. No. 297,899. Dec. 19, 1928.

Apparatus for rolling tubes. M. Roeckner, Mülheim-Ruhr, Germany. No. 297,945. Jan. 30, 1928.

Apparatus for rolling tubes. M. Roeckner, Mülheim-Ruhr, Germany. No. 297,946. Jan. 30, 1928.

Apparatus for rolling tubes. M. Roeckner, Mülheim-Ruhr, Germany. No. 297,947. Jan. 30, 1928

Apparatus for rolling tubes. M. Roeckner, Mülheim-Ruhr, Germany. No. 297,948. Jan. 30, 1928.

Spark plug electrode. (Alloy of nickel with alkali or alkaline earth metals.) The A. C. Spark Plug Co., Flint, Mich., assignee of O. S. Duffendack, Ann Arbor and H. Rabezzana, Flint, Mich. No. 297,975. Sept. 17, 1928.

Feed roller mechanism. The American Sheet and Tin Plate Co., Pittsburgh, Pa., assignee of C. E. Moore, Gary, Inc. No. 297,979. Mar. 13, 1929.

Hot mill catcher. The American Sheet and Tin Plate Co., Pittsburgh, Pa., assignee of D. Buccicone, Gary, Ind. No. 297,980. May 16, 1929.

Permanent mold for making castings. The Dominion Brake Shoe Co., Ltd., St. Thomas, Ont., assignee of J. S. Thompson, New York, N. Y. No. 298,002. Nov. 5, 1926.

Method of making composite metallic articles. The Haynes Stellite Co., Kokomo, Ind., assignee of W. A Wissler, Jackson Heights, N. Y. No. 298,035. May 23, 1927.

Electro-depositing apparatus. The McCord Radiator and Manufacturing Co., assignee of W. W. McCord, both of Detroit, Mich. No. 298,052. Oct. 24, 1929.

Centrifugal casting apparatus. The National Iron Corp., Ltd. of Canada, Toronto, Ont., assignee of W. Gillhausen, Dortmund, Westfalen, Germany. No. 298,055. May 25, 1927.

Chromium-plating conductive bodies. La Société Nouvelle de l'Orfêvreries d'Ercuis, assignee of A. Hollard, both of Paris, France. No. 298,077. Dec. 29, 1928.

Soldering means. Victoria-Werke Akt.-Ges., assignee of J. Schmitt, both of of Nürnberg, Germany. No. 298,082. Jan. 8, 1929.

Rolling mill. J. E. Fries, Birmingham, Ala. No. 298,093. May 14, 1929.

Control for electric furnaces. E. C. Glitzke, Kansas City, Mo. No. 298,121. Nov. 19, 1927.

Method and apparatus for handling sheet metal. R. T. Romine, Mount Clemens, Mich. No. 298,146. May 23, 1927

Method and apparatus for shipping sheet metal. R. T. Romine, Mount Clemens, Mich. No. 298,147. July 27, 1928.

Electrode holder (for welding electrodes). M. Wells, Los Angeles, Calif. No. 298,169. Mar. 19, 1929.

Machine for rolling metal tubes, rods, etc. The Imperial Chemical Industries, Ltd., London, assignee of J. Hollins, Middlewich, Cheshire; and D. Jepson, Glossop, Derbyshire, England. No. 298,239. Jan. 11, 1929.

Forging machine. The National Machinery Company, assignee of W. L Clouse, both of Tiffin, Ohio. No. 298,265. Sept. 8, 1920.

Treatment of impurity precipitates obtained from metallurgical solutions. The Rhodesia Broken Hill Development Co., Ltds., assignee of R. H. Stevens, G. C. Norris and W. M. Watson, all of Broken Hill, Northern Rhodesia, South Africa. No. 298,270. July 30, 1928.

Method of making ingot molds. E. Gathmann, Baltimore, Md. No. 298,561. July 18, 1929.

Tin plate package. H. D. Scott, Wheeling, W. Va. No. 298,600. May 11, 1929.

Method of welding. The Air Reduction Co., Inc., New York, N. Y., assignee of J. L. Anderson, Tenafly, N. J. No. 298,612. Dec. 22, 1928.

Manufacture of cooking utensils. (Welding on of aluminum-silicon alloy handles.) The Aluminum Company of America, Pittsburgh, Pa., assignee of J. H. Wilson, New Kensington, and I. W. Wood, Parnassus, Pa. No. 298,614. Feb. 1, 1929.

Bearing (Copper-lead-phosphor tin). The General Motors Research Corporation, Detroit, Mich., assignee of H. M. Williams, Dayton, Ohio. No. 298,655. May 3, 1927.

Mechanically worked zinc product. The New Jersey Zinc Co., New York, N. Y., assignee of W. M. Peirce and E. A. Anderson, both of Palmerton, Pa. No. 298,680. Dec. 31, 1928.

Method of manufacturing lead-headed nails. A. J. Deniston, Jr., Chicago, Ill., assignee of E. V. Swangren, Maywood, Ill. No. 298,723. June 20, 1929.

Danish Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Press for pressing and stamping sheet metal and the like. F. Humphries, Parkstone, England. No. 41,605. Nov. 25, 1926.

Recuperative annular muffle furnace. A. McD. Duckham and Woodall-Duckham (1920) Ltd., London, England. No. 41,630. (Addition to Patent No. 40,255.) Aug. 11, 1928.

Process and apparatus for electric welding. Steel and Tubes Inc., Cleveland, Ohio. No 41,686. Mar. 1, 1927.

Centrifugal process and apparatus for making pipes or similar hollow bodies. Hume Steel Ltd., Melbourne, Victoria, Australia. No. 41,713. Feb. 4, 1929.

Recuperative annular muffle furnace. A. McD. Duckham and Woodall-Duckham (1920) Ltd., London, England. No. 41,714. Aug. 11, 1928.

Magnetic material. Electric Research Products Inc., New York, N. Y. No. 41,749. Aug. 27, 1925.

French Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Improvements to machines for twisting metal strips. The American Brass Co. No. 680,727. Aug. 23, 1929.

Structural steel. Fried Krupp Akt.-Ges. No. 680,487. Aug. 10, 1929.

Device for distributing the charge in furnaces, particularly in furnaces used for electrothermic processes. G. Hilger. No. 680,669. Jan. 10, 1929.

Process for making bars or billets for rolling, of non-ferrous metals having a high crystallization velocity. Vereinigte Aluminium Werke Akt.-Ges. No. 680,707. Aug. 22, 1929.

Bimetallic pieces which are hot-rollable and process for making them by soldering a layer of copper-zinc alloy to the metal forming the base. Metallgesellschaft Akt.-Ges. No. 680,730. Aug. 23, 1929.

Improvements to reverberatory furnaces. W. F. Sklenar. No. 680,790. Aug. 24, 1929.

Melting furnace. E. Wirges. No. 680,815. Aug. 26, 1929.

Process for refining pig iron. B. Sturenberg. No. 680,854. Aug. 27, 1929.

Ferrous metal. Link Belt Co. No. 680,922. Aug. 28, 1929.

Process for heat treating metals. Link Belt Co. No. 680,923. Aug. 28, 1929.

Furnace for hardening metal in bundles and having a conveying screw. H. Lindhorst. No. 680,924. Aug. 28, 1929.

Process for increasing the breaking strength of a plated light metal. Durener Metallwerke Akt.-Ges. No. 680,501. Aug. 19, 1929.

Machine for the centrifugal casting of hollow bodies. A. Possenti and C. Scorza. No. 680,520. Aug. 20, 1929.

Improvements to apparatus for metallizing by melting and spraying metals. Société Nouvelle de Metallisation. No. 680,554. Dec. 7, 1928.

System and apparatus for supplying molten metal to centrifugal machines for casting hollow bodies. A. Possenti and C. Scorza. No. 680,627 Aug. 21, 1929.

Method of stripping castings having the form of solids of revolution from sand molds. A. Possenti and C. Scorza. No. 680,696. Aug. 22, 1929.

Apparatus for making balls by passing the blanks between rolls rotating in the same direction but with different peripheral speeds. A. Putsch. No. 680,706. Aug. 22, 1929.

Casting method resulting in the ready breakability into small pieces of products for soldering or brazing iron, steel, etc. Société Manufacture de Plaques & Poudres a Souder. No. 680,903. Aug. 28, 1929.

Centrifugal sand distributor for filling foundry flasks and the like. W. Seidemann. No. 680,911. Aug. 28, 1929.

Process, apparatus and molds for the manufacture of zinc cups for elements of piles, batteries, etc. A. Gassan and P. Ruck. No. 680,607. Aug. 20, 1929.

Improvements to electrodes for electric batteries, electrolytic elements and other apparatus. Société Mières, Ltd. No. 680,618. Aug. 21, 1929.

Light alloy. H. T. Tillquist and J. Harden. No. 680,959. Aug. 29, 1929.

Method of operating direct-gas-fired annealing furnaces and furnace for use with this method. Vereinigte Stahlwerke Akt.-Ges. and E. Schreiber. No. 681,356. Sept. 5, 1929.

Improvements to machines for stacking sheets. The Bonnot Co. No. 681,365. Sept. 5, 1929.

Improvement in the manufacture of railroad rails. C. P. Sandberg, O. F. A. Sandberg and N. P. P. Sandberg. No. 681,388. Sept. 5, 1929.

Electric welding machine. F. P. McBerty. No. 681,025. Aug. 3, 1929.

Device for use in gas lines, particularly those for autogenous welding stations. Sulzer Freres (Société Anonyme). No. 681,040. Aug. 30, 1929.

Apparatus for welding sheet aluminum. H. Rosch. No. 681,257. Aug. 3, 1929.

Process and apparatus for casting objects by the action of centrifugal force, and for cooling the castings. Ferric Engineering Co. No. 681,257. Sept. 3, 1929.

Process for increasing the elastic limit of metallic objects. I. G. Farbenindustrie Akt.-Ges. No. 681,305. Sept. 4, 1929.

Improvements to machines for straightening bars and tubing. T. W. Hartley. No. 681,360. Sept. 5, 1929.

New process for soldering the inside of hollow metallic objects. A. Bagnulo. Addition Patent No. 36,280. (First addition to Patent No. 673,757.) Oct. 17, 1928.

Direct-reading pyrometer. Société Arnoux, Veuve Chauvin & Cie. Addition Patent No. 36,377. (Second addition to Patent No. 599,310.) Oct. 15, 1928.

Process for the production of metallic carbonyls. I. G. Farbenindustrie Akt.-Ges. No. 681,083. Aug. 31, 1929.

Runway for the cooling beds of rolling mills. Fried Krupp Akt.-Ges Addition Patent No. 36,333. (Second addition to Patent No. 626,220.) Dec. 12, 1928.

Process for making anti-friction alloys. A. E. Ricard and L. Daniel. No. 681,472. Dec. 29, 1928.

Improvement to machines for separating thin sheets after hot-rolling. Société Anonyme Etablissements J. J. Carnaud & Forges de Basse Indre. No. 681,502. Jan. 10, 1929.

Improvements to apparatus having a heated hearth and a roller conveyor, such as annealing furnaces. N. V. Maatschappij Beheer en Exploitie van Octrooien. No. 681,526. Sept. 9, 1929.

Process for making acid-resistant ferrosilicon alloys. Société Anonyme des Anciens Etablissements Skoda à Pilzen. No. 681,577. Sept. 10, 1929.

Acid-resistant alloy. Société Anonyme des Anciens Etablissements Skoda à Pilzen. No. 681,578. Sept. 10, 1929.

Process for making cast iron and steel containing copper. F. Heusler. No. 681,599. Aug. 20, 1929.

Improvements to molds for casting metals. Aluminum Limited. No. 681,561. Sept. 10, 1929.

Special iron sections. A. Salles. No. 681,592. Mar. 14, 1929.

Process for protecting aluminum against corrosion by alkalies. Elfa Usine Electro-Chimique Aarau W. Francke. No. 681,626. Sept. 11, 1929.

Process for metal tubing for spinning and textile mills. L. Farque. No. 681,772. Sept. 13, 1929.

"Autodoublage" process for the penetrative protection of iron and steel. A. Folliet and N. Sainderichin. No. 681,776. Sept. 14, 1929.

Process for cleaning metallic surfaces. J. H. Gravell. No. 681,836. Sept. 14, 1929.

Method of charging raw materials individually and device for making this charging automatic. P. L. J. Miguet and M. P. Perron. No. 681,468. Dec. 6, 1928.

Electric annealing furnace. Société Anonyme Brown, Boveri & Cie. No. 681,926. Sept. 18, 1929.

New alloy for cartridge cases. Société d'Electro Metallurgie de Dives. No. 681,957. Jan. 11, 1929.

Improvements to metallic mixtures and to processes for making these. R. W. Hyde. No. 682,092. Sept. 20, 1929.

Improvements to aluminum-base alloys. Aluminium Limited. No. 682,251. Sept. 24,1929.

Aluminum-base alloy. Società Accomandita Officine Aquila. No. 682,292. Sept. 25, 1929

Tools for hot-working metals. The Babcock & Wilcox Tube Co. No. 682,306. Sept. 25, 1929.

Process for eliminating the last traces of oxygen from iron, steel or similar alloys. A. Glazunov. No. 682,342. Sept. 26, 1929.

Metallurgical process and apparatus for working it. J. Lambot. No. 682,365. Sept. 27, 1929.

Improvements in the manufacture of cast iron. The British Cast Iron Research Association. No. 682,435. Sept. 30, 1929.

Chemically resistant chromium steels and chrome-nickel steels. Fried. Krupp Akt.-Ges. No. 682,455. Sept. 30, 1929.

Universal rolling mill. Maschinenfabrik Sack G.m.b.H. Addition Patent No. 36,361. (First addition to Patent No. 618,405.) Dec. 29, 1928.

Improvements to hard metallic compositions and to processes for making them. Compagnie Française pour l'Exploitation des Procédés Thomson-Houston. Addition Patent No. 36,376. (First addition to Patent No. 654,210.) Jan. 7, 1929

Refractory lining for the soles of metallurgical and other furnaces and process for making it. Vacuumschmelze G.m.b.H. Addition Patent No. 36,390. (First addition to Patent No. 667,101.) Jan. 10, 1929.

Machine for straightening and rolling sheets. F. Ungerer. No. 681,972. Aug. 13, 1929.

Electric soldering apparatus. Elektrische Lot und Schweiss G.m.b.H. No. 681,982. Sept. 18, 1929.

Device for soldering the longitudinal seams of cans by means of a soldering iron connected to the secondary of a transformer. Elektrische Lot und Schweiss G. m. b. H. No. 681,983. Sept. 18, 1929.

Device for turning gears in hardening baths. F. Klopp. No. 682,079. Sept. 20, 1929.

Process for the elimination from metallic powders of impurities which react with oxygen to form volatile compounds. I. G. Farbenindustrie Akt.-Ges. No. 682,160. Aug. 5, 1929.

Process for making shaped metallic objects. I. G. Farbenindustrie Akt.-Ges. No. 682,162. Aug. 5, 1929.

Pouring nozzle for a centrifugal casting machine. Ferric Engineering Co. No. 682,204. Sept. 23, 1929.

Method of forging and swaging a bar of iron or steel. Société l'Embauchage Electrique Procédés Giacchino. No. 682,314. Sept. 26, 1929.

Process for improving the quality of forged chains of soft steel or wrought iron. Vereinigte Stahlwerke Akt.-Ges. No. 682,349. Sept. 26, 1929.

Process for making castings of high-carbon alloys. E. Piwowarsky. No. 682,350. Sept. 26, 1929.

Plating metals with aluminum or aluminum alloys. Vereinigte Silberhammerwerke Hetzel & Co. No. 682,359. Sept. 27, 1929.

Apparatus for casting metal objects. Krone Sebek Die Casting and Manufacturing Co. No. 682,372. Sept. 27, 1929.

Process for pickling metals. L. Heilbronn. No. 682,426. Sept. 28, 1929.

Process for drawing shells of pure zinc. W. Erfurt. No. 682,438. Sept. 30, 1929.

Improvements in the removal of foreign substances from metallic surfaces. Rex Products & Manufacturing Co. No. 682,466. Sept. 30, 1929.

Improvements in the cleaning of metallic surfaces. Rex Products & Manufacturing Co. No. 682,467. Sept. 30, 1927.

Improvements in the preparation for the elimination of foreign matter from metallic surfaces. Rex Products & Manufacturing Co. No. 682,469. Sept. 30, 1929.

Automatic machine for regulating electric arcs. R. Sarazin. No. 682,422. Sept. 28, 1929.

Process for preventing metals from dissolving in acids. J. H. Gravell. No. 682,424. Sept. 28, 1929.

Nozzle for cleaning metallic objects with a sand blast. P. Lacollonge S.a.r.l. No. 682,673. Oct. 3, 1929.

Fabrication of shaped articles of ferrous alloys. Société Aubert & Duval Freres. No. 682,618. Oct. 2, 1929.

Fabrication of shaped articles of ferrous alloys. Société Aubert & Duval Freres. No. 682,619. Oct. 2, 1929.

Fabrication of shaped articles of ferrous alloys. Société Aubert & Duval Freres. No. 682,620. Oct. 2, 1929.

Improvements in the rolling of sheet metal. The American Rolling Mill Co. No. 682,641. Oct. 2, 1929.

Process for making metallic layers. B. Loewe. No. 683,208. Oct. 12, 1929.

Improvement in the fabrication of embossed metal objects. The Spun Steel Corp. No. 683,267. Oct. 14, 1929.

Process for increasing the safety of operation in the melting zone of electric furnaces having hollow continuous electrodes composed of carbon segments and having a continuous agglomerated core. Mme. Becker, née A. Rees. No. 683,220. Oct. 12, 1929.

Protective device for electric furnaces. L. W. Wild and Wild-Barfield Electric Furnaces, Ltd. No. 683,246. Oct. 14, 1929.

Electrolytic chromium-plating tank. P. Bourgeois. No. 683,275. Oct. 14, 1929.

Process for increasing the radiation coefficient of the thermal absorbtivity and emissivity of metallic surfaces. Vereinigte Aluminium Werke Akt.-Ges. No. 683,235. Oct. 12, 1929.

German Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Rolling process for making carding wire. L. Neuhaus, Dahl, H. Nimmerfall and H. von. der Neyen, Hohenlimburg, Westfalen, Germany. No. 493,191. Oct. 16, 1928.

Disengageable drive for the mechanism for setting the adjusting screws of rolling mills. F. Grah, Hemer, Kr. Iserlohn, Germany. No. 493,192. June 13, 1929.

Automatic-control switching system for roller beds with electrically driven rollers. Fried. Krupp Akt.-Ges., Friedrich-Alfred-Hütte, Rheinhausen, Niederrhein, Germany. No. 493,193. Oct. 28, 1928.

Adjustable backing device for the straightening rolls of sheet-straightening machines. F. Ungerer, Pforzheim, Germany. No. 493,471. Sept. 2, 1928.

Process for making disks, particularly disk wheels, with a central opening and optionally with a cylindrical rim. R. Kronenberg, Haus Kronenberg, Post Immigrath, Germany. No. 493,472. Mar. 10, 1928.

Process for welding thin sheets together and to thicker bodies. A. Ignatieff, Helsingfors, Finland. No. 493,499. Nov. 30, 1926.

Process and device for making flaskless sand molds in two-part molding flasks. New Process Multi-Castings Co., New York, N. Y. No. 493,183. Jan. 24, 1926.

Process for casting copper-zinc alloys in preheated metal molds, aluminum being added to prevent the taking up of oxygen. W. Runde, Lüdenscheid, Germany. No. 493,570. Aug. 22, 1925.

Casting machine for casting molten metals under pressure. E. Brumm, Lyon, France. No. 493,252. Oct. 7, 1924; in France May 1, 1924.

Production of nickel and of chromium alloys. The General Electric Co., Ltd., London, England. No. 493,414. Mar. 23, 1928; in Great Britain Apr. 7, 1927.

Device for detecting inhomogeneities in hollow metallic bodies. Allgemeine Elektricitäts Gesellschaft, Berlin, Germany. No. 493,417. Aug. 28, 1927.

Alloy for welding or brazing copper. L. Rostosky, Berlin, Germany. No. 493,373. (Addition to Patent No. 483,275.) Jan. 25, 1928.

Die-holder for high-speed multiple wire-drawing machines. Les Freres Breguet, Geneva, Switzerland. No. 493,683. Jan. 1, 1929; in Switzerland Dec. 15, 1928

Seam-closing device for hollow sections (Welded-seam tubing). Th. Kieserling & Albrecht, Solingen, Germany. No. 493,684. Jan. 8, 1929.

Catcher for lead-cable presses. Fried. Krupp Grusonwerk Akt.-Ges., Magdeburg-Buckau, Germany. No. 493,867. July 12, 1928.

Process for making metallic hose. O. Meyer-Keller & Cie., Lucerne, Switzerland. No. 493,930. Aug. 2, 1926.

Device for intermittently feeding pieces to presses, stamps, etc., by means of a single chain running about a horizontal axis. L. Schuler Akt.-Ges. Göppingen, Württemberg, Germany. No. 493.849 May 22, 1927.

Process for making benzine tanks from their longitudinal halves. F. E. Krauss, Schwarzenberg, Sachsen, Germany. No. 493,578. Aug. 19, 1928.

Machine for making balls, particularly steel balls, from sections of rod, by means of a stationary conical roll and a rotating conical roll. No. 494,002. (Addition to Patent No. 436,510.) Nov. 11, 1928.

Process for the production of pure iron. I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. No. 493,778. June 11, 1925.

Process for the production of iron by thermal decomposition of iron carbonyl. I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. No. 493,874. (Addition to Patent No. 485,639.) July 6, 1926.

Blast refining process in which the pulverized fuel, ore and limestone or other flux is introduced into the blast from below, through the converter bottom. Eisen-u., Stahlwerk Hoesch, Akt.-Ges., Dortmund, Germany. No. 494,011. Feb. 19, 1928.

Electric resistance furnace. Allgemeine Elektricitäts Gesellschaft, Berlin Germany. No. 493,894. Oct. 24, 1925; in the United States, Oct. 23, 1924.

Casting machine, in which the mold is closed by hydraulic pressure and held together by increased hydraulic pressure. The United States Aluminum Co., Garwood, N. J. No. 493,855. Jan. 19, 1927; in the United States Sept. 1, 1926.

Casting machine in which the halves of the mold are rotatably mounted. I. D. Travis, Salt Lake City, Utah. No. 493,900. Sept. 25, 1927.

Portable automatic breaker for breaking up pig iron in the pig beds. Demag Akt.-Ges., Duisburg, Germany. No. 493,902. June 26, 1928.

Removal of iron from ferronickel and ferrocobalt. Société Anonyme "Le Nickel," Paris, France. No. 494,023. Jan. 28, 1927; in France, Feb. 23, 1926.

Process for working up manganese ores. John C. Wiarda & Co., Brooklyn, N. Y. No. 494,024. Mar. 9, 1927.

Process for preventing hydrogen evolution in electrolytic baths. R. Blasberg, Merscheid, Ohligs, Germany. No. 493,572. Jan. 26, 1928.

Process for treating sheets in a dipping bath. F. E. Krauss, Schwarzenberg Sachsen, Germany. No. 493,910. May 19, 1928.

Derusting process. I. G. Farbenindustrie Akt.-Ges., Frankfurt, a.M., Germany. No. 493,743. Mar. 1, 1928.

Process for increasing the corrosion-resistance of objects made of magnesium alloys. I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. No. 493,827. Feb. 3, 1928.

Soldering device for joining two symmetrical pressed-metal halves to form a hollow body. A Speidel, Pforzheim, Germany. No. 493,636. Aug. 28, 1928.

Welding rails and the like by means of superheated molten metal. Elektro-Thermit G.m.b.H., Berlin-Tempelhof, Germany. No. 493,637. June 6, 1928.

Process for making hollow drill steels. Fagersta Bruks Aktiebolag, Fagersta, Sweden. No. 493,935. Oct. 28, 1926; in Sweden Oct. 9, 1926.

Silvery alloy. I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. No. 494,153. July 30, 1926.

Device for preventing edge proliferation in aqueous electrolysis. I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. No. 494,193. Feb. 19, 1927.

Apparatus for heat treating metal wire, strip, etc. Patent-Treuhand-Gesellschaft für elektrische Glühlampen m.b.H., Berlin, Germany. No. 494,154. Dec. 4, 1928.

Process for producing oxidic coatings on light metals in oxidizing solutions. Dr. Otto Sprenger Patentverwertung Jirotka m.b.H., Vaduz, Liechtenstein. No. 494,262. July 31, 1927.

Process for making turbine blades by rolling. C. A. Parsons, Newcastle-on-Tyne, England. No. 494,164. Nov. 14, 1928; in Great Britain Nov. 17, 1927.

Device for regulating the heating of metals. Gewerkschaft Kronprinz, Bonn a.Rh., Germany. No. 495,094. Feb. 23, 1927.

Conveyor roller, directly driven by a special electric motor, particularly for the roller beds of rolling mill installations. Demag Akt.-Ges., Duisburg, Germany. No. 495,077. Feb. 6, 1927.

Delivery braking device for rolling mills. Fried. Krupp Grusonwerk Akt.-Ges. Madgeburg-Buckau, Germany. No. 494,701. Dec 20, 1928.

Multiple wire-drawing machine. Berkenhoff & Drebes Akt.-Ges., Asslar, near Wetzlar, Germany. No. 495,012. (Addition to Patent No. 482,864.) Nov. 24, 1927.

Extrusion press, with tilting catcher. Fried. Krupp Grusonwerk Akt.-Ges., Madgeburg-Buckau, Germany. No. 494,798. Oct. 21, 1928.

Hot-drawing bench with interchangeable mandrels. Press-und Walzwerk Akt.-Ges., Reisholz, Germany. No. 495,004. (Addition to Patent No. 440,647.) July 4, 1924.

Process for making smooth sheet-metal pipe bends. J. Göpfert, Dresden, Germany. No. 494,777. May 20, 1927.

Sheet drawing device. L. Schuler Akt.-Ges., Göppingen, Württemberg, Germany. No. 494,702. Jan. 19, 1929.

Process for making pouring lips on drawn vessels. Siemens Elektrowärme Gesellschaft m.b.H., Sörnewitz, near Meissen, Germany. No. 495,095. July 7, 1926.

Machine for drawing slotted sheet metal. The General Fireproofing Co., Youngstown, Ohio. No. 494,799. Jan. 25, 1925.

Method of making a cage for radial ball bearings by stamping and pressing from sheet metal. Aktiebolaget Svenska Kullager Fabriken, Göteborg, Sweden. No. 494,703. Jan. 16, 1924; in Sweden Jan. 19, 1923.

Machine for straightening pieces of wire, particularly sewing machine needles. The Singer Manufacturing Co., Elizabeth, N. J. No. 494,686. Nov. 15, 1924.

Process and machine for making single- or double-walled bodies of revolution having a bottom from rotatably mounted metal disks, without the use of a mandrel. Westfälische Metallwerke Goercke & Cie.Komm-Ges., and W. Klöckner, Annen, Westfalen, Germany. No. 494,704. Apr. 17, 1927.

Furnace for annealing, hardening and forging with automatic intermittent feeding of the material by means of up-and-down moving hearth elements between which lie stationary elements. J. Droste, Wandsbek, Hamburg, Germany. No. 494,812. Sept. 21, 1928.

Induction furnace. M. Baermann Jr., Köln, Germany. No. 494,725. Sept. 5, 1925.

Heating coil arrangement for high-frequency melting furnaces. C. Lorenz Akt.-Ges., Berlin-Tempelhof, Germany. No. 495,006. Mar. 31, 1925.

Introduction of atomized water into the melting zone of shaft melting furnaces. Vulcan-Feuerung Akt.-Ges., Köln, Germany. No. 495,124. Dec. 25, 1926.

Ramming machine, especially for ramming very high cylindrical molds having a small diameter. Halbergerhütte, G.m.b.H., Brebach a.d. Saar, Germany. No. 495,125. July 27, 1928.

Process for the simultaneous production of metallic salts and hydrogen sulphide from sulphidic ores. I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. No. 494,633. Dec. 4, 1925.

Process for the production of light metals by fusion electrolysis. Cie. de Produits Chimiques et Electrométallurgiques Alais, Froges et Camargue Paris, France. No. 494,956. Apr. 28, 1928; in France Dec. 21, 1927.

Electrolytic process for the production of thin, superposed, separable layers of nickel or similar metals. E. Breuning, Hagen, Westfalen, Germany. No. 494,788. Aug. 7 1926.

Process for joining constructional elements firmly together by dip soldering. G. W. Christoph, Hartford, Connecticut. No. 494,746. Oct. 23, 1928.

Process for making brake shoes. C. Piehler, Berlin, Germany. No. 494,789. (Addition to Patent No. 493,680.) May 31, 1927.

Process for ornamenting metallic surfaces by applying figures of metal foil or depositing such by electrolysis. H. Debach, Geislingen a.d. Steige, Germany. No. 494,999. Aug. 27, 1927.

Process for rolling smooth tubing and for rolling tubing to size in Pilger rolling mills. Mannesmannröhren-Werke, Düsseldorf, Germany. No. 495,246. June 27, 1928.

Roller conveyor for rolling mill installations. Siegener Maschinenbau Akt.-Ges., Siegen i. W., Germany. No. 495,440. Apr. 21, 1929.

Roller bed with interchangeable guides. T. Weymerskirch, Differdingen, Luxembourg. No. 495,247. Oct. 23, 1928.

Machine for rolling disk-shaped objects. Budd Wheel Co., Philadelphia, Pa. No. 495,248. Apr. 18, 1926.

Electric bright-annealing furnace. Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. No. 495,189. Dec. 4, 1925.

Apparatus for the crystallographic investigation of materials by means of X-rays. Siemens-Reiniger-Veifa Gesellschaft für medezinische Technik m.b.H., Berlin, Germany. No. 495,468. July 8, 1927.

Process for the electric resistance welding of pieces crossing each other. Allgemeine Elektricitäts Gesellschaft, Berlin, Germany. No. 495,563. (Addition to Patent No. 479,785.) Apr. 6, 1927.

Gas-firing installation for furnaces and blast heaters. J. Stoecker and A. Rein, Bochum, Germany. No. 495,469. Apr. 6, 1927.

Process for chromium-plating metals. Rawas Maatschappij, Swalmen, Netherlands. No. 495,581. July 22, 1926.

Italian Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Electrolytic process, especially applicable to the manufacture of certain metalloids, metals, alloys, binary and more complex compounds. L. J. Andrieux, Grenoble, Isère, France. No. 263,852. Oct. 29, 1927; in France Dec. 1, 1926.

Process for purifying magnesium and its high percentage alloys. I. G. Farbenindustrie Akt -Ges., Frankfurt a.M., Germany. No. 264,219. Nov. 12, 1927; in Germany Nov. 13, 1926.

Improved alloys and their application to telegraph and telephone conductors. W. S. Smith, Benchams, Devonshire; J. H. Garnett, Lymne, Kent; and J. A. Holden, Sunnyside, Essex, England. No. 264,166. Nov. 3, 1927; in Great Britain, Nov. 6, and Dec. 17, 1926.

Corrosion-resistant aluminum alloy. Vereinigte Aluminium Werke Akt.-Ges., Lautawerk, Laustiz, Germany. No. 264,150. Sept. 17, 1927; in Germany Sept. 18, 1926.

Process for producing highly porous metallic aggregates. I. G. Farbenindustrie Frankfurt a.M., Germany. No. 264,306. (First addition to Patent No. 258,166, filed May 7, 1927.) Dec. 13. 1927; in Germany Dec. 13, 1926.

Machine for making steel tubing. Barzanò and Zanardo, Milano, Italy. No. 264,014. Nov. 9, 1927; in France Nov. 17, 1926, in the name of A. Portevin.

Improvement to the driving mechanism of metallurgical spray pistols to obtain variable speed of feed of the metal wire. A. Bessé, Cuneo, Italy. No. 263,864. Nov. 11, 1927.

Improvement to method and apparatus for rolling metal disks. Budd Wheel Co., Philadelphia, Pa. No. 264,108. Nov. 3, 1927; in the United States Nov. 3, 1926, in the name of J. W. Hughes.

Machine for drawing fine metal wire. Drahtindustrie Peter Darmstadt, Frankfurt a.M., Germany. No. 264,080. Nov. 18, 1927; in Germany Feb. 21, 1923, in the name of J. K. Lorösch, O. Lorösch and A. Lorösch. (German Patent No. 432,199.)

Multiple wire-drawing machine for fine and very fine wire. Drahtindustrie Peter Darmstadt, Frankfurt a.M., Germany. No. 264,233. Nov. 21, 1927; in Germany Oct. 19, 1923, in the names of O. Lorösch and E. Lorösch. (German Patent No 425,270.)

Process for rolling sheets and strips of iron and other metals together with aluminum or aluminum alloys. Eisen-u. Stahlwerk Hoesch, Dortmund, Germany. No. 264,069 Nov. 10, 1927.

Process for seam-welding sheet iron plated with aluminum, and for making vessels of this material. Eisen-u. Stahlwerk Hoesch, Dortmund, Germany. No. 264,271. Nov. 10, 1927.

Method of degreasing metals and the like. Imperial Chemical Industries Ltd., London, England. No. 263,883. Nov. 26, 1927.

Process for the production of nuclei of limited size in cast iron. Machinenfabrik Esslingen, Neckar, Württemberg, Germany. No. 264,267. Nov. 7, 1927; in Germany Nov. 20, 1926.

Process and apparatus for producing masses containing metallic powder. F. Rahtjen, Hamburg; and M. Ragg, Wentorf, Holstein, Germany. No. 264,215. Nov. 8, 1927.

Composition for use in the autogenous welding of aluminum. W. Reuss, Mannheim, Germany. No. 264,090. Nov. 10, 1927.

Machine for the continuous casting of metals in chill molds. Società Alti Forni, Fonderie, Acciaieri e Ferriere Franchi-Gregorini and Piero Cortesi, Brescia, Italy. No. 263,981. Nov. 27, 1927.

Improvements to rolling processes, especially processes for rolling thin sheets. Société d'Études et de Constructions Métallurgiques, Paris, France. No. 264,043. Oct. 29, 1927; in Belgium Nov. 22, 1926.

Process for making bimetallic bearings by use of a melt formed of layers of different metals or alloys having different melting points. Eisen-u. Stahlwerk Walter Peyinghaus, Egge, Volmarstein a.d. Ruhr, Germany. No. 264,292. (Addition to Patent No. 258,640, filed Nov. 9, 1926.) Oct. 25, 1927.

Improvements to method of making hollow drill steels. Fagersta Bruks Aktiebolag, Fagersta, Sweden. No. 264,385. (First addition to Patent No. 260,944, filed Aug. 24, 1927.) Aug. 25, 1927; in Sweden Feb. 9, 1927.

Process for making bodies of refractory metals. N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands. No. 264,304. (Second addition to Patent No. 217,361, filed Jan. 20, 1923.) Dec. 13, 1927; in the Netherlands Feb. 7, 1927.

Improvements to fusible alloys for soldering and to method of making them. American Machine and Foundry Co., New York, N. Y. No. 264,618. Nov. 9, 1927.

Improvements to blast furnaces. Broken Hill Proprietary Co., Ltd., Melbourne, Victoria, Australia. No. 265,158. Dec. 16, 1927; in Australia Dec. 9, 1926.

Refractory alloy having high electrical resistivity. A. G. H. von Kantzow, Hallstahammar, Sweden. No. 265,069. Dec. 13, 1927; in Sweden Dec. 15, 1926.

Process for making steel having little tendency to brittleness. H. Meyer, Hamborn a.Rh., Germany. No. 264,779. Nov. 17, 1927; in Germany Dec. 6, 1926.

Method of working annealing furnaces using a protective gas. Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. No. 265,156. Dec. 6, 1927; in Germany Dec. 9, 1926, in the name of Siemens-Schuckertwerke G.m.b.H.

Process for making pure iron and steel. H. J. Van Royen, Hörde, Westfalen, Germany. No. 265,162. Dec. 14, 1927; in Germany Dec. 14, 1926.

Aluminum alloy which is resistant to sea water. Vereinigte Aluminium Werke Akt.-Ges., Lautawerk, Lausitz, Germany. No. 274,561. Sept. 16, 1927; in Germany Sept. 18, 1926, in the name of R. Müller.

Hardening metals. H. Lindhorst, Berlin, Germany. No. 264,900. (First addition to Patent No. 263,345, filed Aug. 31, 1927.) Oct. 3, 1927.

Means and method for welding chain links, rings and other ornamental objects. G. Brunhübner, Pforzheim, Germany. No. 264,590. Nov. 19, 1927.

Improvements to processes for rendering metals, especially iron and steel, resistant to rusting, and materials used in this process. W. H. Cole Paris, France. No. 264,975. Mar. 15, 1928.

Apparatus for preparing foundry sand. M. Olivo, Milano, Italy. No. 264,998. Nov. 28, 1927.

Process for making metallic powders. Trefileries et Laminoirs due Havre Anciens Etablissements Lazare Weiller et Société Cooperative de Rugles et la Calalisation Electrique Réunies, Paris, France. No. 264,852. Dec. 1, 1927.

Resistance heating element for electric furnaces. T. D'Alfonso, Rome, Italy. No. 265,161. Dec. 13, 1927.

Method and device for introducing water into the melting zone of shaft melting furnaces and blast furnaces. Vulcan Feuerung Akt.-Ges., Köln, Germany. No. 265,198. Dec. 15, 1927.

Improvements to electric furnaces. Société Electrométallurgique de Montricher, Paris, France. No. 264,915. (First addition to Patent No. 253,303, filed Dec. 17, 1927.) Dec. 19, 1927; in France Oct. 26, 1927,

Process for separating metals from their solutions. H. Bardt, Berlin-Schöneberg, Germany. No. 265,420. Dec. 30, 1927; in Germany Jan. 22, 1920. (Importation of Germany Patent No. 352,783.)

Process for producing inoxidizable steel having a low carbon content and a high chromium content. A. L. Field, White Plains, N. Y. No. 265,226. Dec. 13, 1927; in the United States Dec. 18, 1926.

Process for surface improvement of objects of aluminum and aluminum alloys. Sprenger Corp. m.b.H., Berlin, Germany. No. 265,515. Dec. 27, 1927.

Norwegian Patents

Subject of Invention, Patentee, Patent No., and Filing Date.

Process for preventing the hardening by nitrization of certain parts of objects which are to be hardened by nitrization. Aubert & Duval Frères, Paris, France. No. 47,162. Mar. 13, 1928.

Process for the production of molded carbonaceous objects. The Roessler & Hasslacher Chemical Co., Perth Amboy, N. J. No. 47,227. May 8, 1926.

Process for providing aluminum or aluminum alloy wire, strip or the like with an adherent, elastic, insulating coating. Spezialfabrik für Aluminium-Spulen und Leitungen G.m.b.H., Berlin, Germany. No. 47,310. Dec. 21, 1927.

Magnesium-silicon alloy for the pistons of internal-combustion engines. I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. No. 47,326. Aug. 6, 1927.

Electrolysis of ferric chloride. S. I. Levy and G. W. Gray, London, England. No. 47,335. Feb. 29, 1928.

Process for the treatment of steel and its use in the production of rolled steel. N. Das Chopra and F. J. Bullen, London, England. No. 47,336. Dec. 30, 1926.

Electric annealing furnace. Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. No. 47,340. July 25, 1927.

Means for suspending the electrodes of open electric furnaces. Société Electro-Métallurgique de Montricher, Paris, France. No. 47,363. Mar. 27, 1926.

Construction of top-charged electric furnaces. (Combined arc and induction furnace.) H. Röchling and W. Rodenhauser, Völklingen a.d.Saar, Germany. No. 47,364. Jan. 10, 1927.

Device for jointing baked electrode sections on to the partially consumed electrodes of electric furnaces. Siemens-Planiawerke Akt.-Ges., für Kohlefabrikate, Berlin-Lichtenberg, Germany. No. 47,365. May 27, 1927.

Construction of electric induction furnaces. The Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa. No. 47,366. July 12, 1927.

Means for electrically insulating the electrodes of electric melting furnaces from the mechanism for moving them. Akt.-Ges., Brown, Boveri & Cie., Baden, Switzerland. No. 47,367. Sept. 23, 1927.

Method of heating moving elongated bodies by electricity. Ajax Electrothermic Corp., Trenton, N. J. No. 47,369. Nov. 12, 1927.

Holder for jointed electric furnace electrodes. Siemens-Planiawerke Akt.-Ges. für Kohlenfabrikate, Berlin-Lichtenberg, Germany. No. 47,370. May 27, 1927.

Process for obtaining valuable constituents from ores in their natural state. B. Hofseth, Sungei Besi, Selangor, Malay States. No. 47,429. May 20, 1927.

Roller bed for rolling mills with individual electric drive for each roller. B. Quast and F. Lomberg, Rodenkirchen, near Köln, Germany. No. 47,446. Nov. 21, 1928.

Alloy and application thereof. American Machine & Foundry Co., New York, N. Y. No. 47,468. May 31, 1928.

Process for the production of calcium carbide or ferrosilicon. Gebr. Siemens & Co., Berlin-Lichtenberg, Germany. No. 47,492. June 12, 1925.

Method of introducing air or other gases into the charge inside rotary furnaces. G. Bojner, Karlstad, and A. H. Pehrson, Norrnäs, Oskar-Fredriksborg, Sweden. No. 47,507. Apr. 21, 1927.

Process for preventing the formation of blowholes in ingots of rising, particularly low-carbon, steel. D. Williams, Massillon, Ohio. No. 47,534. Feb. 13, 1928.

Swedish Patents

Subject of Invetion, Patentee, Patent No. and Filing Date.

Process for reducing ores. Nybergs Grufaktiebolag, Smedjebacken, Sweden. No. 69,179. (Addition to Patent No. 65,683.) June 4, 1925.

Process for producing ferrochromium alloys. R. Wild, Holmesfield, and B. D. Wild, Sheffield, England. No. 69,180. Feb. 1, 1923; Priority Dates Mar. 1, Apr. 1 and June 21, 1922.

Means for heating annular bodies uniformly. A. G. E. Hultgren Söderfors, Sweden. No. 69,181. May 2, 1927.

Process and apparatus for making pipes by centrifugal casting. C. Billand, Kaiserslautern, Germany. No. 69,194. Feb. 2, 1927; Priority Date Feb. 2, 1926.

Process for reducing ores. Nybergs Grufaktiebolag, Stockholm, Sweden. No. 69,231. Dec. 23, 1927; Priority Date June 29, 1927.

Molding machine. New Process Multi Castings Co., New York, N. Y. No. 69,240. Jan. 29, 1926; Priority Date Nov. 3, 1925.

Process for producing alloys containing aluminum and chromium. J. Hardén, Lidingö, and H. T Tillquist, Stockholm, Sweden. No. 69,242. Sept. 1, 1928.

Process for making an alloy containing tungsten carbide or molybdenum carbide. Fried. Krupp Akt.-Ges., Essen, Germany. No. 69,243. May 1, 1929; Priority Date May 2, 1928.

Electrolytic process for refining crude aluminum or aluminum alloys. Société Anonyme pour l'Industrie de l'Aluminium, Neuhausen, Switzerland No. 69,244. Dec. 29, 1926; Priority Date Jan. 27, 1926.

Swiss Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Process for metal-coating a foundation body. Metallbank und Metallurgische Gesellschaft Akt.-Ges., Frankfurt a.M., Germany. No. 135,987. June 19, 1928; in Germany June 23, 1927.

Process for protecting metal objects, particularly iron or steel objects against corrosion. W. H. Cole, Paris, France. No. 136,058. Mar. 7, 1928; in Great Britain Mar. 19, 1927.

Process for the production on objects made of aluminum or aluminum alloys, of a coating which is not altered by air, moisture, and which gives an improved appearance. Sprenger Corp. m.b.H., Berlin, Germany. No. 136,059. Dec. 3, 1927.

Process for producing coatings on metals. Dr. Otto Sprenger Patent-verwertung Jirotka m.b.H., Vaduz, Liechtenstein. No. 136,060. Feb. 21, 1928.

Iron-nickel alloy. Fried. Krupp Akt.-Ges., Essen-Ruhr, Germany. No. 136,094. Nov. 21, 1928; in Germany Dec. 24, 1927.

Process for improving zinc and zinc alloys. P. D. Brenna, Fischenthal, Zürich, Switzerland. No. 136,095. Jan. 30, 1928.

Light magnesium-aluminum alloy and process for making the same. A. Kratky, Wien, Austria. No. 136, 096. Apr. 10, 1928; in Austria Nov. 8, 1927.

Mold for duplex bearings. Eisen- und Stahlwerk Walter Peyinghaus, Egge, near Volmarstein a.d. Ruhr, Germany. No. 136,097. Sept. 29, 1927; in Germany Oct. 1, Dec. 21, 1926 and Feb. 18, 1927.

Process for producing rolled aluminum and aluminum alloy wires having uniform strength over their entire length. Vereinigte Aluminium Werke Akt.-Ges., Lautawerk-Lausitz, Germany. No. 136,979. Feb. 5, 1929; in Germany Feb. 27, 1928.

Method of joining horizontal pipe sections by fusion welding. Buss Akt.-Ges., Basel, Switzerland. No. 136,980. Jan. 11, 1929.

Multiple draw bench. Les Frères Breguet, Geneva, Switzerland. No. 136,-982. Dec. 15, 1928.

Die holder for wire-drawing machines. Les Frères Breguet, Geneva, Switzerland. No. 136,983. Dec. 15, 1928.

Process and apparatus for annealing and quenching sheet metal. Aluminium Industries Akt.-Ges., Neuhausen, Switzerland. No. 136,987. Jan. 30, 1929; in Germany Feb. 6, 1928.

Process and apparatus for annealing strip metal. Hirsch Kupfer-und Messing-werke Akt.-Ges., Messingwerk, near Eberswalde, Germany. No. 136,988. Feb. 9, 1929; in Germany Feb. 11 and June 4, 1928.

Method of heating material and electric melting furnace for use with this method. J. Schachtler, Magadino, Tessin, Switzerland. No. 137,031. Nov. 16, 1927.

Mechano-pneumatic device for setting the electrodes of electric furnaces. Société Electro-Métallurgique de Montricher, Paris, France. No. 137,032 Sept. 19, 1928; in France Feb. 7, 1928.

Annular multiple-hearth furnace for continuous processes. Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. No. 137,033. Oct. 19, 1928; in Germany Nov. 12, 1927.

(*Continued from page 507*)

Lithium metal, as such, has no known use owing to its softness and rapid deterioration by water, but in recent years considerable research has been made to determine the possibilities of alloying lithium with other light metals such as beryllium and aluminum. In 1920 United States patent 1,333,965 was issued to Frank A. Fahrenwald for an alloy of extreme lightness, fair permanence and considerable hardness, in which the component parts were lithium and beryllium.

The beryllium is alleged to protect the lithium from oxidation by moisture or heating and from further action if oxidation has begun by producing upon the surface of the alloy a closely adherent, finely textured insoluble oxide that prevents further oxidation. The lithium content may be as high as 25%. This alloy apparently does not corrode faster than iron, and its specific gravity is only about 1.5. By increasing the proportion of lithium to about 65% an alloy as light as water can be produced, and although such an alloy corrodes fairly rapidly in the presence of water it can be protected sufficiently for many purposes by plating or covering. If the percentage of lithium is increased slightly about 65%, small quantities of aluminum or zinc may be added to increase the hardness and strength, but the alloy will retain a specific gravity little or no greater than that of water.

Aluminum to which a very small percentage of lithium has been added has been used to a limited extent in Germany for trucks and bed frames of street and railway cars. This alloy is exceptionally strong.

Since lithium oxide has a low fusion point, lithium has been suggested as a deoxidizer of copper.

The minerals from which caesium, rubidium and lithium may be extracted occur in only a few regions in the United States, principally in California, South Dakota, New Mexico and Maine.

The market for caesium, rubidium and lithium is extremely limited, and for lithium only is there any demand at present.

The principal market for lithium minerals is in the Eastern States. Practically all of the lepidolite mined in California is shipped in crude form to Wheeling, W. Va., and there pulverized for use in the glass trade. Most of the spodumene and amblygonite mined in South Dakota is shipped to Maywood, N. J. for conversion into lithium salts and chemicals.

Additional details are given in Information Circular 6215, "Caesium, Rubidium and Lithium," copies of which may be obtained from the United States Bureau of Mines, Department of Commerce, Washington, D. C.

Detroit A. S. T. M. Regional Meeting

The annual spring Group Meeting of the committees of the American Society for Testing Materials was held in Detroit on March 17th to 21st. The attendance at this meeting was large considering that Detroit did not offer the usual Atlantic City swimming and watching the bathers—in fact the attendance was phenomenal for a meeting devoted chiefly to committee work.

The long-winded reading in full of papers already preprinted was not only unnecessary but time-consuming, seriously cutting down the time for discussion. It was a wonder the audience stuck around as well as it did. It is hoped that other arrangements will be made in the future.

The papers gave a very excellent bird's eye view of the various subjects they discussed and will be fully abstracted in the Current Literature Review.

Dr. Johnson is to be complimented for the refreshing style of his paper, "Corrosion and Heat-Resisting Steels as Applied to Automobile and Bus Use," with its homely allusions and unstilted phraseology. Too many authors seem to feel that it is undignified to be natural and interesting. We are all prone to take ourselves and our effusions too seriously and it is a relief to find an author who can combine information and interest.